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MODEL NETS

A National Study of Computer Networking in K–12 Education

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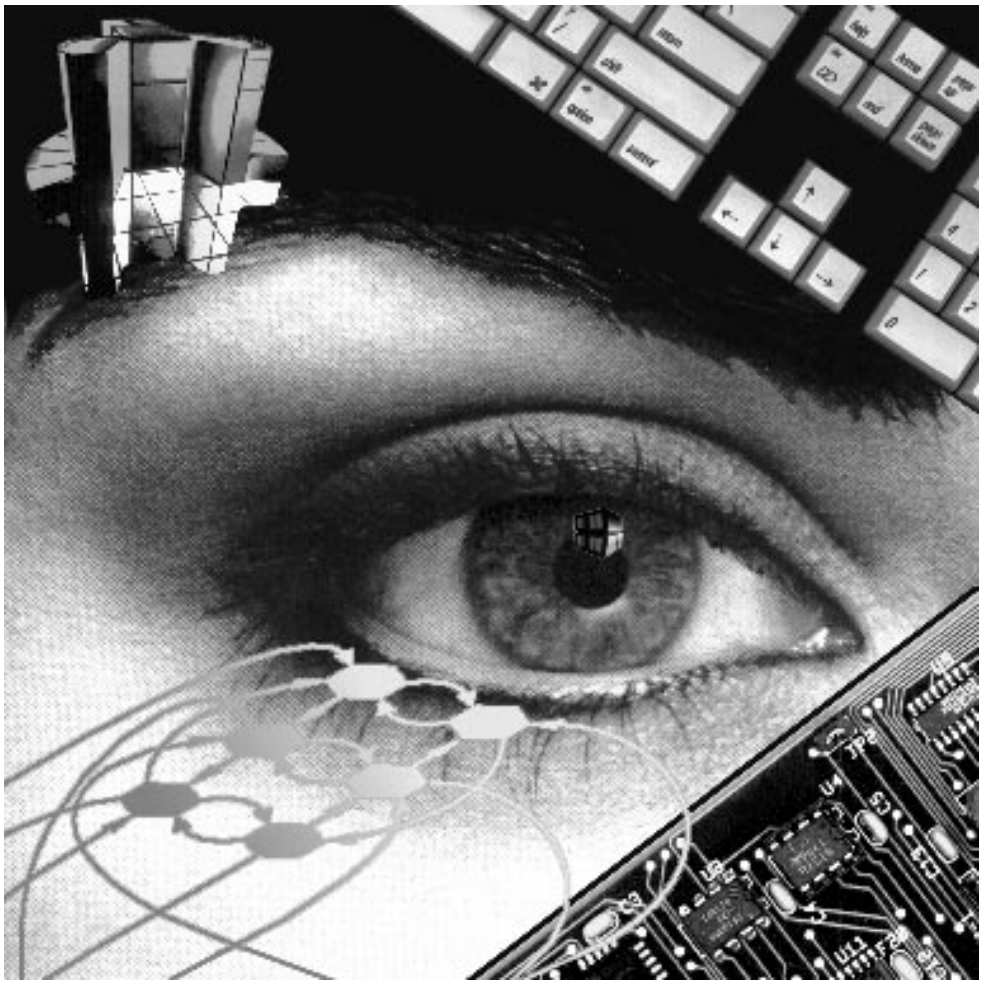

Los Alamos
NATIONAL LABORATORY

Model Nets

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A National Study of Computer Networking in K–12 Education

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Introduction

This report documents the methodology and findings of Model Nets, a national study of the characteristics of computer networks that positively impact teaching and learning in grades kindergarten through 12 (K–12). For the purposes of this study, we defined "positive impact" to be uses of a network that support a discovery-based and student-centered model of learning in which students explore, discover, create, propose explanations and solutions, and take action on what they have learned. This model influenced the study design and methodology.

The Model Nets study originated approximately two years ago to address needs expressed by a consortium of federal agencies responsible for funding networking projects. The agencies included the Department of Energy, Department of Education, National Science Foundation, Department of Commerce, Department of Agriculture, National Aeronautics and Space Administration, Advanced Research Projects Agency, and National Institutes of Health. Responding to a national mandate to network all schools, the consortium voiced interest in identifying criteria they could use to select the best and most appropriate projects. They also wanted information about successful scale-up and expansion of existing network environments.

Los Alamos proposed a study, which was subsequently funded by the Department of Energy, that would be sufficiently wide in scope to develop and support recommendations about how federal agencies can make the most effective use of taxpayers' dollars in funding networking technology projects in K–12 schools. We designed the study to identify and describe those characteristics that either enhance or create obstacles to implementing effective computer networking in schools. Using the data collected during the study, we developed a set of guidelines for implementing effective computer networks (starting on page 67). These guidelines can help federal agencies in making funding decisions related to networking technology projects in K–12 schools. The guidelines also will be useful to school districts as they plan and implement computer networks.

Design of Study

With several factors in mind based on the needs of federal agencies and of school districts, we set out to design a study that would

- incorporate previous research about effective use of computer networking in school districts;
- draw upon the computer networking knowledge of a team of experts in network technology and education;
- incorporate site visits comprising interviews, focus groups, observations, and document reviews to examine a large, diverse set of districts across the country using computer networks; and
- conduct a survey of all teachers at the districts in the study to determine their use of computer networks and to complement the findings of the site visits.

We conducted the study in three phases:

- Phase I: Planning the Study. This phase included reviewing literature and previous research, forming a project planning team, developing data collection instruments, and piloting the instruments and approach to site visits.
- Phase II: Collecting the Data. This phase included assembling and training 10 site visit teams, conducting three-day site visits to school districts across the country, and conducting a survey of teachers at those districts.
- Phase III: Synthesizing, Analyzing, and Reporting the Data. This phase included distilling effective practices from site observations and survey responses, writing the report, and creating the guidelines to effective practice.

By complementing descriptive data from the observational site visits with survey data, our methodology provided us with qualitative and quantitative data from a number of perspectives about characteristics of computer network use in school districts. We synthesized this data within the three domains that framed our study: *technical infrastructure*, *policy*, and *teaching and learning.* Based on this synthesis, on the collective knowledge and judgment of our experts, and on the findings of previous research, we compiled the characteristics of effective practice into guidelines. We also developed a list of the barriers that inhibit effective networking.

We centered the observational aspect of our field study on site visits to a national sample of public school districts making widespread use of computer-based networks, as determined by the 10 regional education laboratories (RELs) of the Department of Education. We focused on districts as our unit of analysis for two reasons: (1) we sought to understand the impact of wide area networks (WANs), a technology that transcends individual school use and is best suited to multiple, physically separated sites, and (2) decisions about policy and funding are generally made at the district level. In the regions of the 10 RELs, we selected a sample of sites that represent a range of economics, geography, and demography. Model Nets research

teams conducted visits to 32 districts and a sample of 93 schools within these districts. It should be noted that as the site visits proceeded, we saw considerable variation among districts in their degree of network implementation. This gave us an ideal opportunity to learn more about how schools overcome inherent barriers and constraints in expanding the use of their networks.

During each site visit, the site visit teams interviewed staff, conducted focus groups, observed education practice and facilities, and reviewed existing documentation to collect data from teachers, students, technology coordinators, administrators, and community members. The teams also collected previously distributed written surveys of teachers at each of the schools they visited. Finally, the teams wrote descriptive case studies of the sites, describing the three domains of each site's networking approach that framed our study: the networking technology infrastructure, policy issues concerning the development and use of the network, and teaching and learning practices using the network.

Principal Partners

Throughout the study, Los Alamos engaged in several major partnerships, including those with the University of California–Los Angeles Center for the Study of Evaluation (UCLA), the Department of Education through its RELs, and Boyer & Associates.

UCLA assisted in the design of the study, administered the teacher survey and analyzed the survey data, and participated in Phase III.

The collaboration with the RELs represented one of the first major initiatives between the Department of Energy and the Department of Education under a newly signed memorandum of understanding by the Secretaries of both agencies. The RELs drew upon their relationships with state departments of education, school districts, colleges of education, and other groups in their regions to select sites and site visit teams for their regions. Representatives from the RELs also participated in the data analysis activities of Phase III.

Boyer & Associates facilitated the training for the site visit teams, assisted with supervision of the data collection, and participated in Phase III.

Next Steps

We plan to develop a set of tools, including a handbook and multimedia-based guide, that will translate our findings and recommendations into a user-friendly format to help schools set up their own computer networks. Our plans include distributing information on the World Wide Web, disseminating the guide to schools and districts, and distributing our data collection instruments to help other agencies and school districts continue to explore or evaluate network use in school districts.

Organization of Report

The remainder of this report comprises the following chapters:

Background of Study

- Summarizes the findings of previous, related studies that influenced the research questions which formed the foundation for the Model Nets study. Chapter starts on page 5.

Design and Methodology

- Describes the methods of the study, including the formation and training of site visit teams, the development of data collection instruments for the site visits and the teacher survey, and the procedures for gathering and analyzing the data. Chapter starts on page 15.

Descriptive Findings

- Reports a synthesis of the data gathered through site visits and an analysis of the teacher survey; discusses obstacles to effective computer networking. Chapter starts on page 29.

Guidelines for Implementing Effective Computer Networks

- Outlines the characteristics of effective practice for using computer networks in school districts, where "effective practices" are defined as those that support discovery-based, student-centered learning. Chapter starts on page 67.

Conclusions and Recommendations

- Interprets the significance of key findings, suggests additional avenues for research into computer networks, and presents several recommendations for funding agencies and school districts. Chapter starts on page 73.

Background of Study

Before conducting the study, we perused the pertinent literature (1) to make sure that the study would contribute to the body of knowledge in this area and would not duplicate existing work and (2) to help us refine our preliminary thinking about how we should structure the content of the study. We sought to extend prior work and to improve our ability to frame the research questions such that we could develop a set of instruments that would give us the most useful information.

According to some estimates, by 1988, 65% of the larger school districts in the U.S. used some form of computer networking, and by 1989 that figure had gone up to more than 71% (Gevirtz and Kelman, 1990). It is probably safe to assume that the number is now even greater. But schools are struggling to develop strategies and make choices about technology in a world of accelerating technological change. The rapidity of that change and the increasing pressure to use networking to improve student learning have left a gap in knowledge about the characteristics that contribute to the effective use of computer networking in the schools. Given that the introduction of networking into schools has been relatively recent, potential funders and planners are faced with the task of making funding decisions with little evidence of what works well to guide them.

We found little research on Internet use in precollege education; we found far more research on telecommunications—video networks and distance education. Most research studies on telecommunications in schools concluded that telecommunications could have a significant impact on the ability of schools to reform (or to transition to a discovery-based, student-centered model of learning), but that few actual instances existed where the technology was used pervasively enough to see the kind of impact desired. This information helped us decide to conduct site visits to a national sample of public school districts that were believed to be making widespread use of computer networks.

We found that *no* large-scale studies of network use in schools had tested the assumption that computer networking is a powerful tool that can both help students learn better and help teachers teach better. In a study conducted by a research team led by Collis and Levin (1993),

the majority of available research studies on telecommunications in education were found to "follow a descriptive, single case methodology." They also found that such research frequently failed to provide justification for generalization and failed to identify questions for more in-depth investigation. The team concluded that cross-fertilization and synthesis of research on telecommunications in education were necessary. They encouraged researchers to further develop and refine case-study methodologies in the context of networking technology environments.

While research has been conducted on a variety of aspects of computing in the academic environment, there is still a great deal to learn. In particular, the technology of local area networks (LANs) and WANs is fairly new in the K–12 environment. Information relating to networking has been gleaned primarily from single case studies and from research relating to stand-alone uses of technology. We concluded that existing practice was largely based on experiences that had not been rigorously tested.

As we designed the Model Nets study, we kept in mind a few key factors:

- Purpose. The purpose of the Model Nets study was to identify characteristics of computer networking in K–12 education that positively impact teaching and learning, so as to assist federal agencies in making the most effective funding decisions, especially regarding successful scale-up and expansion of existing network environments.
- Expertise in Computing. We sought to apply the expertise of Los Alamos National Laboratory in computational science to a significant issue in education, namely, computer networking.
- Prior Knowledge. We brought to the study extensive prior knowledge about the importance of policy and leadership issues related to implementing successful education programs.

Based on these factors, we initially structured our study around three aspects, or domains, of networking technology: the *technical infrastructure*, related *policy* issues, and *teaching and learning* practices. Our review of the literature reinforced our decision to use these domains as the structural foci for the content of the study. Further, our review of the literature in these three areas helped us to refine our thinking and to structure our research questions within these three domains. The following review of literature is thus divided into those three areas.

Technical Infrastructure

Much of the research on the potential of networking environments has come from universities and from pilot projects begun in the 1980s. Some research was conducted at the K–12 level by Bolt, Beranek and Newman, Inc. (BB&N), a leading developer of networking hardware and software. BB&N's research has been rooted in the belief that telecommunications with a single phone line and a modem was "an isolated, marginal activity" affecting only single classrooms (Newman, 1992). Consequently, BB&N focused

its research on interrelationships between LANs and WANs, reasoning that schools that were able to bridge the two were capable of equitably distributing access to resources across a broader school community.

In looking for models of "bridged networks," BB&N found few instances where LANs were used to give multiple users access to the Internet (Newman, Bernstein, and Reese, 1992). Working with data from a 1990 survey of over 400 California schools, they noted that 16.5% of the schools reported that they had LANs, 45% had WANs, and only 10.6% had both. Of this 10.6%, none of the schools were using the LANs to distribute data coming from the WANs. Instead the networks supported printing to a common printer, use of networked software, or use of integrated learning systems. In an effort to encourage the use of LANs to support tool-based student projects, BB&N initiated a pilot project that explored the effective uses of LANs for fostering project-based learning within a school and between geographically disparate schools. They set up a server linked to computer stations throughout the school. From any of these stations, students and teachers could access electronic folders, or "virtual workplaces." Teams of students throughout the building used the network to carry work from one context to the next and to collaborate electronically across time periods throughout the school day, without ever needing to physically come together. In general, except in a small number of experiments such as this, LANs do not provide a pedagogical structure and management organization that support student acquisition of higher-order skills (Gevirtz and Kelman, 1992). In schools that have connected their LANs to the WAN, students "quickly take over greater responsibility for their projects and their exploration of the Internet resources" (Newman, 1993).

For Model Nets, we had made a preliminary decision to select sites that showed evidence of an established WAN, with electronic communications conducted by two or more schools in the district and with connections via the network to services or entities outside the school district. This decision had been based on the need identified by the consortium of federal agencies interested in this study for information about successful scale-up and expansion of existing networks. It was also based on our desire to identify, as broadly as possible, all the characteristics relevant to implementing a computer network (infrastructure, security, access, locus of control, etc.). We believed that looking at sites with only LAN access would constrain our ability to identify these characteristics. The information we found on WAN and LAN use in K–12 education affirmed our decision about this aspect of our site selection criteria.

Policies

Our thinking about this topic was framed by standard and generally accepted research in the area of administrative leadership. We know that for educational programs to succeed they must be supported by leadership that

- emphasizes the achievement of program goals and adherence to staff performance standards,

- effectively deploys staff and materials, and
- demonstrates a commitment to the success of the program (Longshore, Kaye, and Mandel, 1981).

We also know that effective leadership need not depend on whether any *single* leader is strong in all the pertinent ways. Leadership may also be effective if some *combination* of formal and/or informal leaders in the setting attends capably to the tasks at hand (Fleishman and Harris, 1962). We also know that staff involvement—breadth of involvement, degree of involvement, formality of involvement, and staff commitment—are crucial to the success of a program (Longshore et al.). There is a close conceptual and empirical connection between administrative leadership and staff involvement. "Strategic leaders are people who have a clear vision—based on a widely shared set of values and aspirations—of where their organizations should be heading and who can clearly articulate that vision in a manner that motivates others" (Mauriel, 1989).

Schools are struggling to develop strategies and make choices about technology and to emphasize the achievement of program goals and adherence to staff performance standards with respect to technology and networking. These difficulties are made apparent by the lack of district-wide plans for technology applications. Perhaps because of the rapid pace of technological change, networking and technology appear to be particularly difficult areas for which educational leaders find themselves newly responsible. These leaders find themselves in a situation in which they must take risks and stretch their imaginations. "Leaders are pioneers—people who are willing to step out into the unknown. They are people who are willing to take risks, to innovate and experiment in order to find new and better ways of doing things" (Kouzes and Posner, 1987).

The absence of districtwide plans for technology applications has been cited as unacceptable by such divergent sources as the National Governors Association (1986), the National School Boards Association (1987), and the U.S. Office of Technology Assessment (1988). It is not uncommon for a school district to spend hundreds of thousands of dollars on computers and other components of a technology support system without a curriculum-based plan for their use. The plans that do exist are often based on faulty and piecemeal strategies and tactics. Further, some of these plans do not define a strategy for bringing about the transformation of curriculum and instruction using technology for both a catalyst and support (Mojkowski, 1990).

However, school districts and state departments of education seem to be increasingly interested in administrative data exchange systems that would make student records accessible to district, state, and federal authorities, and perhaps even to colleges and universities. A study conducted by the California Department of Education in 1992 determined that existing methods for exchanging data cost the state more than $50 million a year, with each transaction costing $15 and taking 24 hours to transfer. Department analysts concluded that electronic networking would reduce the transfer costs three-fold and substantially improve the state's ability to share data in a timely fashion with different

agencies (California Department of Education et al., 1992). This alerted us to the fact that we needed to be cognizant, throughout our study, of the usefulness of networks for administration, and not just for instructional purposes.

Our study was designed to identify the types of policies in place that either enhance or create obstacles to the effective implementation of a computer network. We used our review of this literature to help us identify additional issues related to policy that we wanted to investigate, such as leadership, vision, planning, etc.

Teaching and Learning

The constructivist educational philosophy holds "that children actively construct their knowledge . . . and emphasizes the careful study of the processes by which children create and develop their ideas" (Strommen and Lincoln, 1992). One important feature of constructivism is collaborative learning, a process in which students collectively construct ideas, learning from what they already know, with peers viewed as resources of information. The key features of collaborative learning are a changed relationship between teacher and student and a resource-rich, activity-based curriculum for learning. There is now widespread agreement among educators that the advanced skills of comprehension, reasoning, composition, and experimentation are acquired not through the transmission of facts but through the learner's interaction with content (Collins, Brown, and Newman, 1989).

A variety of literature on learning suggests that networking technology can help students learn better and help teachers teach better and that it can encourage a constructivist learning approach. The research also suggests that networking technology can motivate students to learn more and perform well. Another suggested benefit of technology is that it provides tools that begin to introduce and reinforce the skills that students will need in the work force. The effect of these tools, such as a word processor, can be even more pronounced when used in a networked environment, with students reviewing and editing the work of other students. Thus, the tool essentially facilitates a new social organization in which reading and writing take place (Riel, 1989). Strommen and Lincoln propose that technology plays a special role in this type of "child-driven learning environment" by serving as a tool for "learning by doing" (Strommen and Lincoln, 1992). Because of a general agreement about the usefulness of the constructivist approach to teaching and learning, because much of the research and literature we found on computer networks reported its results in this context, and because our study was not designed to determine the impact of networking on *student learning*, we decided to look at teaching and learning practices that support this constructivist approach. Additionally, to identify the broadest set of teaching and learning practices, we determined that one of our site selection criteria would be evidence that the district integrated electronic networking throughout various components of the school system, particularly instruction.

Student Learning and Motivation

In 1988, Krendl and Lieberman synthesized research on computers and learning conducted during the 1980s, citing 111 different research and theoretical references. Much of the literature during this decade related to stand-alone computing applications and not to telecommunications per se. The literature revealed the following:

- Use of computer applications led to an increase in self-reports of motivation and learning (Kulik, Kulik, and Bangert-Drowns, 1984).
- Use of tools helped children to become more proficient in related processes (for example, word processors led to more proficient writing) (Souviney and Miller-Souviney, 1986).
- A "functional learning environment" with access to others improved writing (Newman, 1984; Riel, 1985; Riel, 1986; Cohen and Riel, 1986).
- Using computer-assisted instruction (CAI) led to an increase in both academic achievement and perceptions of learning based on effort (Henderson, Landesman, and Kachuck, 1985; Vickers, 1984).
- Science knowledge and skills were positively affected when a computer was used as a tool in the science lab (Linn, 1986; Nachmias and Linn, 1986).
- More positive effects were found when novices were provided with less user control and more experienced users with more user control (Krendle, 1988).

In one study of changes in information-seeking patterns when students were given access to either print or electronic encyclopedias, researchers found that eighth graders using electronic media conducted both broader and deeper searches. Students with access to only print resources conducted far more limited searches and used fewer cross-referencing techniques (Krendl et al., 1985). Other researchers found that computer use in informal, student-centered settings promoted active, independent learning, reduced drudgery, and helped make abstract concepts concrete (Bork, 1985; Krendle, 1988; Kulik et al., 1984).

In 1993, the Center for Technology in Education (formerly Bank Street College) conducted the first-ever large-scale survey of K–12 telecommunications practices. The 550 respondents from 48 states were solicited based on their extensive classroom experiences with computing technology. This highly specialized group represented pioneers in using telecommunications for precollege education. Survey results characterized teachers' perceptions about the types of curricular projects and goals that had the greatest value using telecommunications. Science, social awareness, and cultural projects were perceived to be the most effective activities; news services and scientific databases were perceived as the most useful information retrieval activities; and the most highly rated goals included expanding students' awareness about the world, accessing information that otherwise would be difficult to obtain, and increasing inquiry-based and analytical skills (Honey and Henriquez, 1993).

With these goals in mind, the developers of the AT&T Learning Network have integrated telecommunications into their curriculum for K–12 students. This project was initiated as an experimental collaboration between elementary students in Alaska and California and later developed to interconnect students from the United States, Mexico, Japan, and Israel. Activities included news writing, science projects, and social science topics, and also focused on problem solving skills (Levin, Riel, Miyake, and Cohen, 1987; Riel, 1989).

In one application of a network discussed by Riel (1989), students used a computer-based news wire service to exchange stories on breaking events in their respective regions. Students' writing during this project was found to improve beyond grade-level expectations, with dramatic improvements found for students teamed with the teachers who had previous experience with the technology. The role of editing other students' work through this process has been emphasized as important, as well as the fact that the computer serves to "create an environment" (Riel, 1989).

In another use of this network, students were engaged in distributed problem solving through the network to tackle water shortage, a problem shared by students in all of these countries. By tackling this common problem, students learned to transfer solutions from elsewhere to their own problems, and also "acquired science concepts in the instructional setting that provided dynamic support for the acquisition of problem solving skills" (Levin, Riel, Miyake, and Cohen, 1987). These results suggest the benefit of the "teleapprenticeship" model for learning, in which both novice and expert can learn from each other in remote locations. Apprenticeship impacts the nature of knowledge that students acquire, as it embeds the learning of skills and knowledge in their social and functional context (Collins, Brown, and Newman, 1989).

In her work with the AT&T Learning Circles, Riel (1989) found that computer networking promoted "changes in the relationships among students, changes in the teacher-student relationship, and differences in the relationship of the teacher to other educators," thus creating a new social organization in the classroom. In 1986, Johnson and Johnson suggested that, perhaps capitalizing on this new social organization, an increase in performance was seen when the strategies of cooperative learning and technology-based learning were paired (Krendle, 1988).

KidsNet was another network-based project that enabled students to engage in "real" problem solving activities with others outside of their classroom, providing "student-centered, project-based experiential learning." Teachers reported that having a computer, modem, and access to KidsNet was both a highly motivating and educational experience for teachers and students alike, and that science seemed more "real" when placed in the context of these telecommunications activities. These activities were also found to expand students' previously insular views about the world (Jackson, Doster, Tippins, and Rutledge, 1994).

Literature indicates that technology can broaden students' educational involvement through challenging, extended tasks or projects that require active engagement and application of knowledge (Sheingold, 1991). Respondents to the Bank Street survey indicated that, for their

students, they were primarily concerned with expanding students' awareness, enabling them to access resources, and increasing their higher-order thinking skills. The majority felt that they had seen positive effects on both their own teaching and their students' learning (Honey and Henriquez, 1993). The immediacy of communications afforded by networks provides both teachers and students with access to rich arrays of up-to-date information and interpretive tools for manipulating and analyzing this information. Networks also support a collaborative environment by providing access to drafts and works in progress for peer review and comment, and access to libraries of exemplars or final mastery products for communal discussion on desirable standards and outcomes. Additionally, publication of student work and recognition for their accomplishments can be a powerful motivator for students and an important indicator for communities of success of school programs (Sheingold, Roberts, and Malcom, 1992).

Although we had a sense, going into this study, of what we wanted to investigate with respect to student use of networks (those practices that support a constructivist approach to learning), this literature and research helped provide us with examples of the kinds of networking practices that we would see if networks were being used in ways that would most effectively support this constructivist approach.

Workforce Readiness

Because of "the globalization of commerce and industry and the explosive growth of technology on the job" (U.S. Department of Labor, 1991) since 1975, both the conditions under which young people enter the workforce and the associated skills needed to maintain a job in our society have changed. The SCANS report identifies the *competencies* and *foundation* which comprise what is referred to as *workplace know-how,* essentially defining effective job performance today. The five competencies (resources, interpersonal, information, systems, and technology), along with a three-part foundation of skills and personal qualities (basic skills, thinking skills, and personal qualities), lie at the heart of job performance. The report states that to prepare students for today's workforce, schools must teach these competencies and foundations (U.S. Department of Labor, 1991). The research findings of studies in which telecommunications/networking technology has been implemented provide evidence that many of these competencies and skills are addressed with educational programs that make use of the technology, and they helped us to remain cognizant of the potential use of networking to prepare students for the workforce, regardless of whether this is done within a broader instructional context.

Teacher Development

Survey responses from the 1993 Bank Street study suggested that educators receive minimal administrative support for their activities, that they are largely self-taught, and that their chief incentives for embarking on telecommunications are to combat their own classroom isolation and to exchange ideas and information related to their teaching. They also noted that widespread acceptance of the technology by their colleagues would take place only with

more time and more attention to teacher training. More than two-thirds of the educators in the study reported that integrating telecommunications in their teaching has positively impacted the way they teach, enabling them to spend more time with individual students (Honey and Henriquez, 1993).

Based on findings in a study regarding the effect of direct and unrestricted access to the Internet on high school teachers, Gallo and Horton suggested that use of the Internet can increase teachers' self-esteem and improve their attitudes toward computers and education, that use of the Internet encourages teachers to restructure their classes and schedules to accommodate use of this resource in the classroom, and that for successful implementation teachers require ongoing training, technical support, home access, and time to both learn and incorporate this tool in their classes (1994).

Through an experiment with math and science teachers across the country, the Technology Education Research Center (TERC) concluded that teacher-based networks can be effective for supporting professional development, for sharing information on effective implementation strategies, and for following-up with trainers and colleagues met at conferences, workshops, or institutes (Ruopp et al., 1993). TERC found that most of the teachers using LabNet found ways to integrate the knowledge they acquired into their current teaching practices, and "a small but significant number of teachers went through changes in their teaching and took the difficult road of attempting to fully integrate projects into their science" (Ruopp et al., 1993). The network provided teachers with support as they experimented with new ways of teaching, and it provided new paths for teachers to display leadership as they shared their new educational ideas with others.

The literature cited above helped to cement our thinking about the importance of professional development with respect to networking, and pointed us to some key professional development issues we thought important to incorporate in the present study, for example, how teachers use networking; how teachers receive network training, including when and what type; and what support they are provided to acquire appropriate professional development.

Design and Methodology

Overview

We conducted Model Nets research along two converging data collection tracks: (1) site visits in 32 districts across the country to gather observational and qualitative data using several data collection instruments and (2) a teacher survey at the same districts using a questionnaire to gather quantitative data on teachers' self-reported uses and experiences with computer networks. Site visits combined interviews, reviews of school district documents, focus groups, and observations. The teacher survey gave us yet another perspective on network use in schools by reaching a different and much broader subset of respondents. Documentation from state departments of education, district offices, and individual schools helped validate data collected through other sources. We used these multiple data sources to gain the most accurate perspective on computer network use in schools.

We formulated a set of research questions to frame our investigations and to shape the data collection instruments. The questions focused on three aspects, or domains, of networking technology: infrastructure, policy, and teaching and learning practices. These three aspects also shaped the composition of our site visit teams, which included an expert in each domain.

Work proceeded in three phases:

- Phase I: Planning the Study
- Phase II: Collecting the Data
- Phase III: Analyzing, Synthesizing, and Reporting the Data

Each phase is described in greater detail in the following sections.

Phase I. Planning the Study

To plan the study, we carried out the following activities, some of which are discussed in greater detail below:

- Reviewed existing research and literature on computer networks in K–12 education
- Established the Model Nets approach, which would combine site visit data with teacher survey data from districts around the country to infer the characteristics of effective practice related to implementing computer networks in schools
- Developed preliminary research questions
- Conducted a pre-pilot site visit to a rural school district in New Mexico
- Refined the research questions (summarized on page 17) based on the early pilot
- Created preliminary data collection instruments, strategies, and procedures for site visits
- Piloted the data collection instruments, strategies, and procedures at four additional sites
- Revised the research questions, instruments, and data collection procedures
- Developed criteria for selecting sites
- Developed criteria for selecting members of site visit teams
- Refined strategies and procedures for site visits
- Developed the teacher survey
- Formed a partnership with Department of Education RELs

Initially, we reviewed and discussed the strengths and limitations of existing research on computer networks. Then we assembled a small planning team that included computer infrastructure and teaching and learning specialists from Los Alamos and the Tennessee Valley Authority, a superintendent from a large urban school district, and a social science researcher from the University of Tennessee. With this team, we developed a preliminary set of research questions based on the three domains we had identified as key to the development, implementation, and maintenance of computer networks: the technical infrastructure, related policies, and teaching and learning practices. We used these preliminary questions to guide a pre-pilot site visit to a rural school district that had been experiencing difficulties setting up a network. The 1,500-student district had created an impressive technology infrastructure with no additional funding from outside sources. By redirecting the existing budget, the superintendent had managed to allocate $150,000 per year for purchasing and maintaining equipment and for training staff.

Based on this pre-pilot site visit and on what we learned from our literature review, we identified important gaps in the research and revised our preliminary research questions. We also began to create a structure for the site visits—noting what needed to take place before, during, and after a site visit—and established criteria for preliminary site selections. We

defined districts to be our unit of analysis because at the district level we could study (1) the impact of WANs, a technology that transcends individual school use and is best suited to multiple, physically separated sites, and (2) policy and funding, which are generally decided at the district level.

Our planning team members worked with representatives in their home states to identify potential districts for piloting the data collection instruments and overall site visit approach. During this time, we developed an approach to the pilot site visits, settled on a set of questions and issues to address at site visits, and wrote preliminary strategies and procedures. We drafted separate interview and focus group protocols for district superintendents, district technology coordinators, principals, building technology coordinators, networking teachers, non-networking teachers, parents, students, and others (such as school board members or partners from the business sector). We also created site observation protocols and focus group protocols for teachers and students.

Research Questions

Thirty-four research questions guided us in creating the data collection instruments for the site visits and the teacher survey, in conducting site visits, and in analyzing the data. The questions can be summarized as follows:

- Did the sophistication of the network infrastructure (as measured by its bandwidth; topology; connectivity; capabilities or functions; number, type, and location of networked stations; and performance) appear to have any bearing on the extent of use, impact, and/or integration of the technology?
- Did the development of any particular policies or procedures (related to vision, planning, resource distribution, funding, community involvement, evaluation, leadership, access, or use) appear to have any bearing on the extent of use, impact, and/or integration of the technology?
- Did any particular teaching and learning practices (related to instruction, assessment, administration, professional development, or design of learning environments) appear to have any bearing on the extent of use, impact, and/or integration of the technology?

The complete list of research questions appears in Appendix C.

Piloting the Site Visits

We conducted pilot site visits to four urban and suburban school districts with vastly different demographics in two states. We worked with superintendents and district technology coordinators to plan each visit, which included meeting the superintendent, the director of technology (or equivalent), the director of curriculum (or equivalent), and selected school board members. We interviewed the superintendent one-on-one and the others in small groups.

At each school, we conducted one-on-one interviews with the principal and the building technology coordinator. We observed the school's physical environment and interviewed at

least three teachers one-on-one (including one teacher who did *not* use technology) and five students in a group.

These pilot site visits helped us refine the Model Nets study in several ways. We reduced the number of interview and observation protocols used during our site visits and decided to administer a written survey to collect more in-depth data from a greater number of teachers. We found that many of the questions we were prepared to ask could not be addressed in school districts which had minimal experience with networking. For example, a district that had yet to implement a WAN could not accurately project the costs associated with the network. Thus, our exposure to several districts that were only beginning to implement computer networks helped us to decide that our districts should be selected across the country based on their widespread use of networks.

Developing the Data Collection Instruments and Site Visit Strategies

All data collection instruments—the teacher survey and the instruments for the site visits—were designed to address the research questions described above. Each instrument was targeted to address the knowledge area of the interview subject. For example, the teacher survey focused on issues of teaching and learning and did not include many questions about infrastructure or policy.

As discussed above, we revised the data collection instruments based on our experiences with the pilot site visits. The instruments used for the site visits and the teacher survey are included in Appendix D.

Site Visit Data Collection Protocols and Instruments. We developed the following instruments and protocols for site visits:

- Superintendent Interview. Included questions focused on vision, policy, planning, evaluation, funding, costs and benefits, obstacles, community involvement, impact on the district, and other issues related to computer networks and school district administration.
- District Technology Coordinator Interview. Included questions about computer network implementation at the district in such areas as hardware, connectivity, functions, access, training, patterns of use, performance, technical support, impact, planning, funding, evaluation, barriers, security, etc.
- Principal Interview. Included questions about computer network implementation at the school in such areas as impact on the school, goals, uses, evaluation, policy, involvement of community, training, obstacles, etc.
- Building Technology Coordinator Interview. Included questions about computer network implementation at the school in such areas as hardware, connectivity, functions, access, training, patterns of use, performance, technical support, impact, planning, funding, evaluation, barriers, security, etc.

- Teacher Focus Group Protocol. Included questions about teachers' and students' uses of the computer network, impact, access, training, planning and decision making processes, the physical environment, future needs or wishes, obstacles, etc.
- Student Focus Group Protocol. Included questions about students' uses of the computer network, frequency of use, rules or guidelines, training and support, impact, future needs or wishes, obstacles, etc.
- Classroom or Lab Observation Protocol. Included questions and prompts to structure observation of computer network use in schools.

Site Visit Strategies. We developed a site visit team checklist to standardize procedures that teams followed before, during, and after the site visits. During their site visits to districts, site teams collected data using the above described instruments and protocols. They also gathered documentation for later review. Note taking, facilitated by the use of interview forms developed for this project (described below), was often supplemented by video and audio recordings and by still photographs.

Teacher Survey. Using a preliminary draft developed by the planning team, staff of the UCLA's Center for the Study of Evaluation developed a six-page teacher survey to gather self-reported information on teachers' network practices and their impact on both teachers and students. The survey included several background questions on teachers' grade level, years of teaching experience, and general experience with computers and networking. It also contained a number of questions about the types of network training teachers had received and how effective each type had been. Further, the survey asked teachers how they used networks; if and how their students used networks; where, when, and how long they and their students had access to networks; and what obstacles to network use teachers had encountered.

Questions focused on the impact of computer network use on the instructional practices and professional lives of teachers, on their students, and on the school as a whole. Teachers were asked the extent of administrative support for networking, whether there was a district technology plan, and whether network use was evaluated within their district. Finally, the survey asked five open-ended questions about lessons learned by their school related to initiating a network, their needs for further training, and their feelings if their network access were eliminated. The majority of the questions asked teachers to respond on five-point scales.

Establishing Criteria for Site Selection

We established the following criteria for selecting school districts for participation in the Model Nets study:

1. The school district shows evidence of an *established WAN,* with electronic communications conducted by two or more schools in the district and with connections

via the network to services/entities outside the school district (for example, the Internet, universities, commercial on-line services, etc.).

2. The school district shows evidence that they *integrated electronic networking throughout various components of the school system,* particularly instruction.
3. The total sample of selected sites *represents a blend* of rural and urban districts, small and large populations, diverse socioeconomic levels, and ethnically diverse populations.

Establishing Criteria for Site Visit Teams

We decided that the site visit teams should include an expert in each domain of interest, that is, in infrastructure, policy, and teaching and learning. We also determined that each team should include members who are leaders in educational technology within their regions and that all members be able to devote roughly five weeks of their time to the study. The Model Nets planning team carefully mapped out the following set of characteristics to describe the ideal candidates for each team position.

Criteria for Selecting the Site Visit Teams

Policy Expert
The ideal candidate is a district administrator with experience
- implementing a WAN,
- using the Internet and associated software tools,
- evaluating schools and school systems through team site visits (perhaps as part of an accreditation team), and
- formulating technology policies.

Technology Infrastructure Specialist
The ideal candidate is a technology coordinator with extensive Internet experience, familiar with
- LANs (Ethernet and Token Ring);
- WANs, including analog, digital, and fiber optic;
- IBM and Macintosh operating systems;
- telecommunications software, including TCP/IP, FTP, Gopher, WAIS, Mosaic, and Netscape;
- educational applications software;
- telecommunications policies on a state, regional, and national level; and
- evaluation of technology infrastructure (hardware, software, and policies).

Teaching/Learning Specialist
The ideal candidate is a former K–12 classroom teacher, familiar with national issues associated with curriculum change, with experience
- using educational technology applications;
- using the Internet and associated software tools;
- conducting training in use of educational technologies;
- conducting training in use of innovative teaching, learning, and assessment strategies; and
- evaluating classrooms and schools through team site visits (perhaps as part of an accreditation team).

Phase II. Collecting the Data

In Phase II, we accomplished the following activities:

- Selected site visit teams
- Selected sites
- Trained site visit teams
- Conducted site visits
- Conducted teacher survey
- Compiled data and wrote site visit reports

Selecting the Site Visit Teams

The project drew upon the expertise of the 10 Department of Education RELs to identify and select site visit team members. RELs selected team members based on the criteria developed in Phase I. We formed 10 site visit teams, one from each of the 10 RELs. Because of financial or logistical constraints, two of the laboratories formed teams of two people who had the appropriate backgrounds to divide the tasks and responsibilities between themselves. Additionally, five of the laboratories decided to form teams of more than three members. (See Appendix B for a listing of site visit teams.)

Selecting the Sites

As with the identification of site visit team members, the project drew upon the expertise of the 10 RELs to identify sites for inclusion in the study. In some cases, state departments of education recommended sites. Thirty-two public school districts nationwide, approximately three per REL region (Figure 1), were selected and agreed to participate in this project, based on the criteria developed and defined in Phase I.

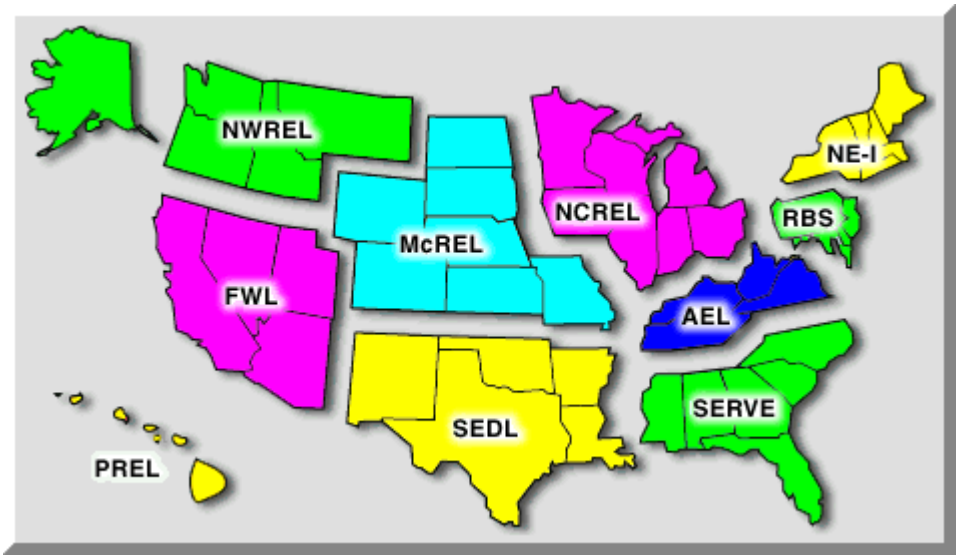

Figure 1. Department of Education RELs.

Sites were selected from 30 states. (See Appendix A for a listing.) Of the 32 sites, 29 were regular school districts (including one district that served an entire state), two comprised a number of smaller districts in their areas, and one was a "virtual high school" that extended its reach to schools in other districts throughout its region. For the sake of simplicity, all 32 entities are referred to as "districts" or "sites" throughout this report.

Once districts had been identified, three schools within each district were selected for site visits. Districts were asked to identify an elementary, a middle, and a high school for each visit. The exact number of schools observed varied slightly from site to site. At several sites, four or five schools were included in the visit for comparison and contrast purposes. At the virtual high school, only the founding hub school was included. And in two cases, all grades K–12 were housed in a single building, so the visit was confined to these buildings.

Profile of Selected Districts

In total, the combined student population for all districts participating in the study was 767,919 (or approximately 1.3% of the total student population of the United States). Figures 2-5 provide a breakdown of the demographics of the districts. They ranged in size from very large (three districts with over 100,000 students) to very small (two districts with fewer than 500 students), with a range of 134 to 180,000 students (Figure 2). The median district population was 24,000 students.

Further, districts ranged in geographic size from 38 sq. km. to 227,559 sq. km., with a median of 8,080 sq. km. Districts had anywhere from 1 to 234 schools under their jurisdictions, with an average of 34 schools.

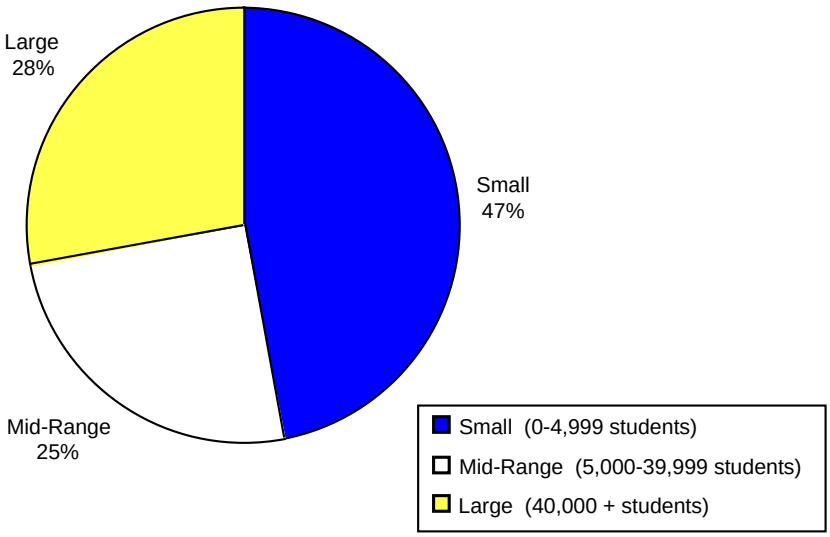

Figure 2. District Size. Data supplied by individual school districts, 1995.

Just over one-quarter (28%) of the sites were in either large or mid-sized urban centers or large towns. And one-quarter of the sites (25%) were in suburbs on the fringes of large or mid-sized urban centers (Figure 3).[1]

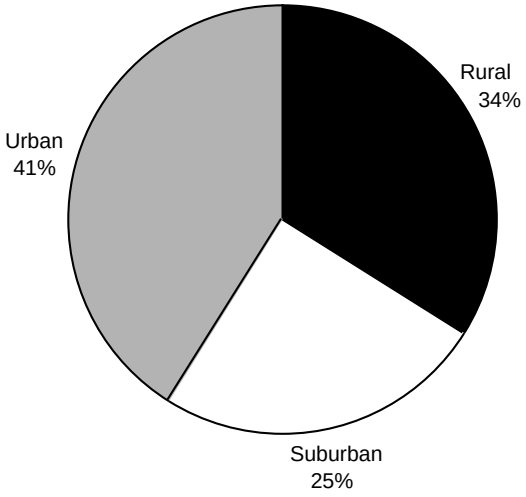

Figure 3. Geographic Characteristics of Districts. Source: National Center for Education Statistics, 1994.

Based on the median income of the community and the percentage of students on free or reduced lunch, the greatest percentage of the districts (41%) were located in middle income communities, where

- low income was defined as a median income of less than $25,000 per year and more than 20% of the students were eligible for free or reduced lunches,

[1] Demographic data for these sites on Figures 3-5 were taken from the *School District Data Book*, compiled by the National Center for Education Statistics (NCES, 1994).

- middle income was defined as a median income of less than $50,000 per year and 10% to 20% of the students were eligible for free or reduced lunches, and
- high income was defined as a median income of more than $50,000 per year and less than 10% of the students were eligible for free or reduced lunches.

Two of the districts in the study, by a variety of different measures, were the most economically disadvantaged districts within their states. Only five (16%) of the selected school districts had median household incomes in excess of $50,000 per year (Figure 4). Median incomes for the sample ranged from a low of $14,477 to a high of $67,389 (Figure 4).

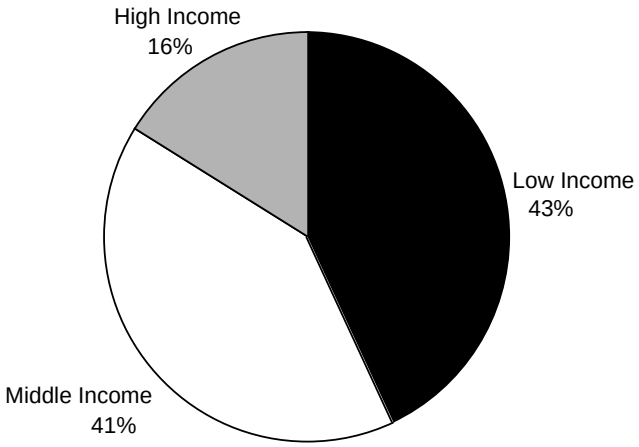

Figure 4. Socioeconomic Characteristics of Districts. Source: National Center for Education Statistics, 1994.

The total student population for all 32 school districts reflects a higher percentage of ethnic minorities (43% of the students) than the national average (28% of the students). Specifically, the Model Nets sample has a higher concentration of Native Americans, African Americans, Asians, and Pacific Islanders and slightly fewer Hispanics than the national average (Figure 5). Twenty-three of the Model Nets school districts had largely Anglo populations (i.e., 50% or more of the students in the district fell within this ethnic group), five were largely African American, one was largely Hispanic, and one was largely Asian.

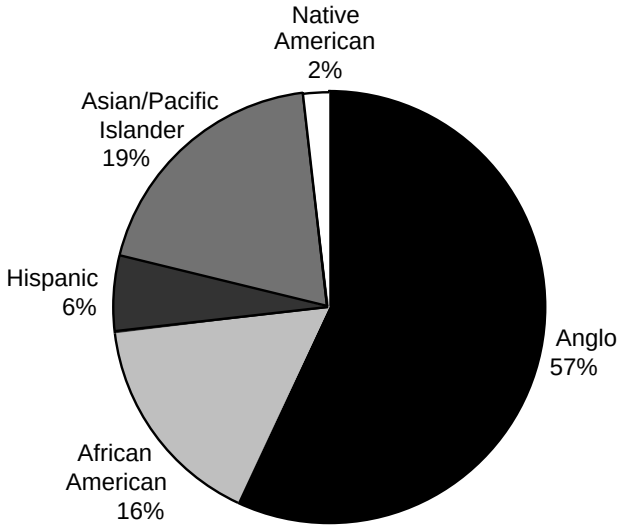

Figure 5. Student Ethnicity across Districts. Source: The National Center for Education Statistics, 1994.

Half, or 16, of the school districts had predominantly homogeneous student populations (i.e., 80% or more of the students belonged to a single ethnic group), and half had predominantly heterogeneous student populations.

Additionally, a number of districts in the sample are participating in different innovative education reform efforts. Ten of the sites are members of the National Science Foundation National School Network Testbed II. Four are recipients of National Science Foundation Networking in Education (NIE) grants, one is an awardee for a Department of Commerce grant, and one is the beneficiary of a major Annenburg/Corporation for Public Broadcasting grant.

Training the Site Visit Teams

Los Alamos staff and Boyer & Associates trained the 10 teams in site visit strategies and use of the instruments and protocols to ensure a standardized approach to all site visits by

- providing an overview of the methodology,
- building a consensus of the meaning of key terminology,
- reviewing all the instruments and protocols, and
- reviewing and refining guidelines for reporting on the site visits.

Conducting the Site Visits

Site teams visited the selected school districts in their respective regions for three days. At each district, the site team asked administrators to select one elementary, one middle, and one high school that they felt represented the most extensive uses of instructional networks within their districts. The teams visited the schools to observe the uses of the network at all levels within a district. The site teams, in some cases, visited more than one school at a

particular level. In districts where two or more levels shared a single building, the site teams generally elected to extend their visit at these schools.

Teams collected data through personal interviews with key administrators and technology coordinators at the school and district levels, focus groups with teachers and students, and informal observations of classrooms and facilities in general. Focus groups included both teachers and students who were active network users and those who were nonusers. The visits followed the protocols and procedures developed in Phase I and described under the Developing the Data Collection Instruments section, page 18.

We also collected documentation from the state departments of education, the district's central office and individual school sites. These documents included the following:

- Demographic profiles of the states, districts, and schools
- Technology plans from states, districts, and schools
- Lists of software recommended by states and districts or used by schools
- State curriculum frameworks
- Staff development plans
- Teachers' lesson plans (on an informal, voluntary basis)
- Student products (on an informal, voluntary basis)

Reporting on the Site Visits

Each site visit team used the data they collected to write a 10-15 page narrative report. The report was organized according to the research questions and summarized data collected through interviews, focus groups, and observations. Reports also included an executive summary that synthesized the team's overall impressions within the three domains of the study.

Conducting the Teacher Survey

While the site visits were taking place, we sent teacher questionnaires to the technology coordinator at each district, who then sent them on with a cover letter to the principal or technology coordinator at each selected school, for distribution to the teachers. Schools returned the surveys either to the site visit teams or to Los Alamos directly.

Phase III. Synthesizing, Analyzing, and Reporting the Data

Our two major sources of data, the site visit reports and teacher surveys, helped us describe networking practices at the districts and identify characteristics of effective practices. To describe practices at the site, we used the site visit reports to derive a list of key elements that elaborate the original research questions in greater detail; we used the teacher surveys as an additional source of information. To identify the characteristics of effective practices, we

convened a group of subject matter experts for an in-depth review of the site visit reports and the teacher surveys.

For the description of networking practices common across sites according to the site visit reports, we developed a matrix that included a list of key elements along one axis and the sites along the other. We tabulated the presence of these elements across the sites, which helped us to summarize and describe the site visit data for the Descriptive Findings chapter of this report.

In addition to these data, we also used information from the teacher survey to support the descriptions of the sites from the site visit reports and to provide additional descriptive data. Analysis of the teacher surveys involved summarizing the nationwide data according to the research questions (for example, training, impact on students, impact on teaching, and so forth), exploring differences that occurred among teachers at different levels of schooling (elementary, middle, and high school) or among districts, and summarizing what teachers said spontaneously in their open-ended responses. In some cases, it was appropriate to report percentages for all teachers who responded to the survey, whereas in other cases it was more appropriate to report percentages of those teachers who responded to a particular item (such as the subset of teachers whose students use networking technology in the classroom). Analyses of five open-ended survey questions refer to a sample of 128 surveys selected randomly from respondents who completed those questions. Findings for these questions are expressed as percentages of this sample.

To identify the characteristics of effective practice, we convened a data analysis team consisting of nine experts in technology infrastructure, policy, and teaching and learning, as well as staff from Los Alamos, the UCLA Center for the Study of Evaluation, and Boyer & Associates. We sent the members copies of the site visit reports. We asked them to read the reports and rate the effectiveness (on a five-point scale) of each district's policies, technical infrastructure, and teaching and learning practices. The team compared and discussed their ratings. Collectively, they established the rationale for their ratings and calibrated the five-point scale for consistency. They also compared the site visit findings with the teacher survey findings to further elucidate effective practices across the three domains. The team then worked in subgroups by domain

- to establish rationale for and further clarify effective practices in each domain,
- to identify examples of effective practices from the districts, and
- to describe obstacles to establishing effective computer networks and potential solutions.

Project staff from Los Alamos and other team members continued examining the reports and the teacher surveys for effective practices and obstacles, and for consistency between the reports and surveys. We also used the teacher surveys to highlight the effective practices observed during the site visits. We based the guidelines (presented later in the Guidelines for Implementing Effective Computer Networks chapter) on a synthesis of these effective practices with the knowledge of effective practices brought to the project by our team of experts.

Descriptive Findings

Reporting the Results

In the following pages, we discuss key findings, background information from the teacher survey, and findings in the three domains of computer networking that we studied: technical infrastructure, policy, and teaching and learning.

The information reported here about use of computer networks is a synthesis of the reports of the site visit teams and the teacher surveys. We report survey data as simple percentages of all respondents, as a fraction of all respondents, or as percentages of respondents to a particular question. We report site visit data as percentages, numbers, or fractions of all districts when the data represent common elements of effective practice. (Please refer to page 26 for a complete discussion of the methodology used to analyze site visit data.) In those cases where the practices of a particular district or a handful of districts merit elaboration, we report those practices anecdotally.

Teacher survey questions focused on the impact of computer networks on the teaching and learning domain and did not address policy or technical infrastructure, two domains in which administrators and technology coordinators were better sources of information. We distributed surveys to teachers at 93 schools in the 32 districts of the Model Nets study. We received surveys from 1,374 teachers at 60 schools in 26 districts, which represented approximately three-fourths of the districts and two-thirds of the schools in the study. Respondents comprised 45% of the teachers in the schools where surveys were completed, and they represented 31% of all teachers in all the schools visited.

Although this was a self-selected group of teachers willing to complete the survey and not a random sample of all teachers in these schools, the returned surveys appeared to represent a cross-section of teachers based both on grade levels taught and years of teaching experience. Thirty-seven percent of the teachers who responded to the survey taught elementary grades (K–5), 27% taught middle school grades (6–8), and 34% taught high school grades (9–12). With respect to years of teaching experience, teachers were also fairly evenly distributed

across all levels. Approximately one-third had taught for 10 years or less, another third for 10-20 years, and the final third for more than 20 years. Additionally, the respondents represented a cross-section of different disciplines within their schools, from elementary reading and art to AP physics and mathematics. Teachers who responded to our survey were not computer specialists. Only 2% were computer science teachers, and only 2% had out-of-classroom assignments of any kind.

Teachers who responded to this survey tended to be familiar with computers. Over a third (37%) of them said they were "very comfortable" with computers, and another 43% indicated that they were "somewhat comfortable." Two-thirds of them (68%) owned a personal computer themselves.

Key Findings of the Model Nets Study

As we reviewed, analyzed, and synthesized the data in preparation for writing the Guidelines for Implementing Effective Computer Networks, we identified several key findings in each domain of the study. In some cases, these key findings were noteworthy because they provided solid reinforcement for commonly held truths about computer networking in schools or because they defied our expectations. In other cases, we felt a finding was key because it emerged as a prominent feature of network use across most sites. Most of these key findings are represented in the guidelines as characteristics of effective practice.

Technical Infrastructure

From the site visits, we found that most districts had originally approached networking for one of two reasons: to support administration or to enhance teaching and learning. Thus, the networks were either partitioned between the two realms or physically separate (that is, two networks, one for each purpose). We found that 18 sites had networks with completely separated administrative and instructional functions. Two networks were focused only on instruction, and 12 were used for both instructional and administrative purposes. Additionally, we found that most sites did not perceive network security or problems with security to be a major concern.

We found that while a majority of the sites had building LANs connected to district WANs, a third of them did not have such connections. This came as a surprise, given that one of our criteria for selecting sites was that the school district show evidence of an established WAN, with electronic communications conducted by two or more schools in the district and with connections via the network to services/entities outside the school district. Many of the districts that we visited were, in fact, still setting up their networks. Yet all but one district had access to the Internet.

Of the five districts that had completed their network installations by the spring of 1995, all were exploring minor network upgrades in 1995-96, but they had no immediate plans to make any major changes to the infrastructure itself. Districts were subject to financial constraints that forced them to implement their plans over time.

Most of the networks were hybrids of various modes of transmission. The bandwidth tended to vary within sites, where different components of the infrastructure had different capabilities. Twenty sites (62%) had a maximum bandwidth of 56 Kbps, which is generally considered the high end of the commonly defined low range. This bandwidth allows the network to carry video and voice data (though marginally, in many cases), in addition to text and graphical data. Four sites had networks running at less than 56 Kbps, while eight sites had networks running at more than 56 Kbps.

Policy

In the domain of policy, the key findings related to vision, leadership and decision making, access, planning, funding, and policy type. In the area of vision, we found that many district visions for computer networking were a combination of increasing administrative efficiency and supporting educational reform or else favored one or the other. In the area of leadership, we found that many districts reported that having a champion to spearhead networking efforts was a critical feature of successful implementation. We also found that decision making was most effective when it was shared between the district and the school site, whereas site-based management created obstacles to successful networking. And a clear majority of teachers felt that they had administrative support for computer networking.

We found that districts developing computer networks frequently were supported by state policies, particularly state reform acts and funding formulas that favored networking. On the other hand, federal policy had less impact on districts. Many sites reported that they were wary of federal policy and entitlement programs, which they reported perceiving as unstable and potentially short-lived. In their own role as policy makers, many districts had established acceptable-use policies that defined appropriate and inappropriate activities on the network. In a related area, most districts were committed to ensuring wide and convenient access to the network for staff and students.

While our site visit teams found that most districts had a computer network plan, the teacher survey results indicated that a large number of teachers believed their districts lacked a plan. This discrepancy may hint at confusion over the planning process or at a lack of communication about the planning process at the district level. However, most districts did not have an evaluation plan to monitor the effectiveness of their networks. To fund its network, every district in the study relied on at least two—and often more—sources of financial support. Many districts showed an entrepreneurial bent in developing creative ways either to fund the network or to obtain equipment and software without expenditures.

Teaching and Learning

As we looked at the use of computer networks in support of teaching and learning, one finding emerged consistently from a variety of teacher survey questions: computer networks are a force in elementary schools more than in middle schools and in middle schools more than in high schools. This was true for impact on students, on teachers, on classroom practices, and on schools overall.

We found that the most common teacher uses of computer networks were to access information and resources and to perform administrative tasks. Teachers were receiving professional development in how to use networks but not in how to best use the technology for instruction. And while all teachers had access to the network, not all students did; however, about one-fifth of the teachers surveyed had *never used* a computer network.

Most student use of computer networks was to access information, either locally or on the Internet. By using networks, students developed skills in accessing and locating information and in communications. Our data also showed that students and consultants were equally effective in providing training to teachers on using the network. The most effective method of training was by district and school technology coordinators and by teachers' peers.

We also found that use of computer networks helped to increase the presence of community members in school affairs.

Technical Infrastructure

Configuration

The site visit teams found that the majority of the Model Nets districts (20 sites or 63%) had WANs linked to building LANs (Figure 6). Another five of the districts (16%) had laid the infrastructure for a WAN but were only able to take the wiring to the school walls because their schools did not yet have LANs in place. The reverse situation was true for eight districts (25%), where schools had LANs in place, but the districts had yet to build WANs to connect them all.

Decisions about whether to simultaneously pursue WANs and LANs, or to make one a priority over the other, generally reflect differences in the impetus behind the networking endeavor (for example, either driven by the central office or by the school site) and timelines and budgets for completion of work. Because of time limitations and financial constraints, most districts had to phase-in their networks incrementally.

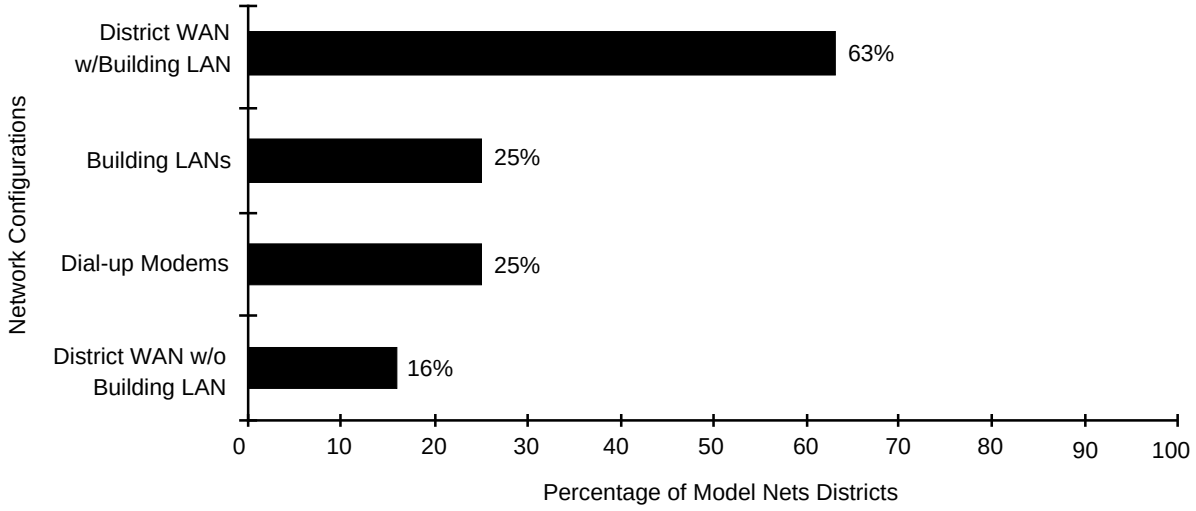

Figure 6. Network Configurations of Districts.

Transmission Media

The majority of the networks (26 sites or 81%) were hybrids employing two to four different transmission media, according to the reports of the site visit teams (Figure 7). Using dial-up modems over regular phone lines was still the common denominator for most districts (94%), providing reliable external connections to individual schools, as districts implemented their networks. These dial-up modems often supplemented other means of network connectivity. But six of the sites in the study were relying strictly on dial-up modems for their Internet connections.

Two-fifths of the sites (41%) were using optical fiber. Approximately one-fifth were using frame relay (22%), one-fifth were using leased digital lines (19%), and one-fifth were using ISDN (19%) and/or coaxial cable (16%). Most of the sites used more than one medium. Coaxial cable and ISDN were generally found in urban or suburban locales. Sites using ISDN technologies, for example, were concentrated along the West Coast and in major metropolitan areas.

Three rural sites (9%) were employing microwave, although another three sites said they were considering upgrading and expanding their networks using microwave within the next couple of years. A single, geographically remote site was found to be using satellite-based Internet transmissions.

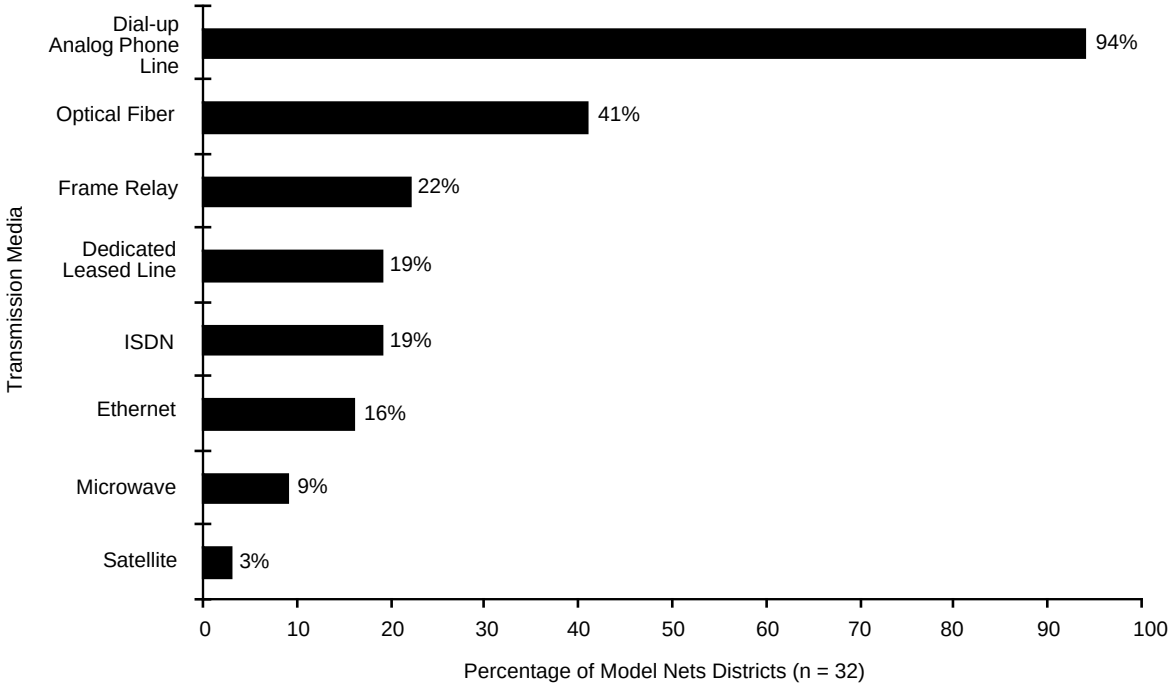

Figure 7. Transmission Media of Districts.

Bandwidth and Capabilities Available

The spectrum of bandwidth ranged from one urban network operating at speeds of 100-155 Mbps to one rural district's dial-up modem connections functioning at 9.6 Kbps (Figure 8). The majority of the districts (24 sites or 75%) had a maximum bandwidth of 56 Kbps. Four sites had bandwidth of less than 56 Kbps, while eight sites exceeded that line speed. A bandwidth of 56 Kbps is generally considered to be the threshold for barely acceptable performance using video or voice applications. Despite marginal bandwidth for applications that for optimal use require a bandwidth higher than 56 Kbps at most districts, they were using their networks to support video, voice, graphical, multimedia, and other applications, such as video teleconferencing, graphical World Wide Web browsers, etc. In the districts, voice was defined as real-time telephone transmission; video was defined as real-time, full-motion video transmission. However, most districts had not yet brought their networks up to this capability. Instead, they were running applications to simulate full voice and video capability, but at lower quality.

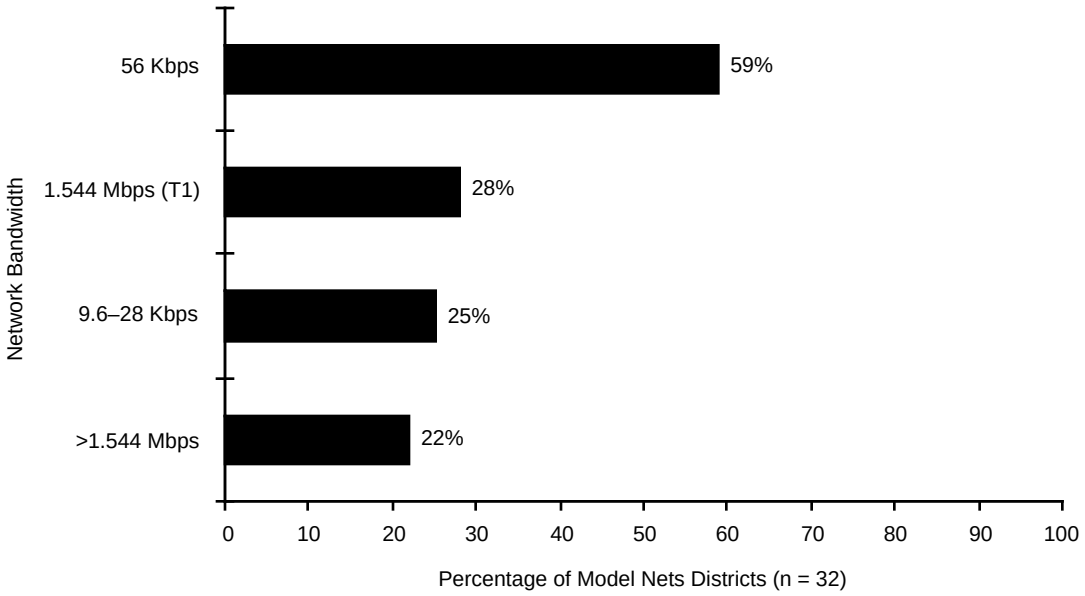

Figure 8. Occurrences of Various Network Bandwidths in Districts.

Half, or 16, of the districts could fully support voice, video, and data on their networks, although in most sites the voice and video capabilities were separate networks from the computer network. Two more districts ran limited video teleconferencing applications over their computer networks. A quarter of the sites had older computer platforms that were incapable of running graphical interfaces. Sites that were unable to support voice or video either were using a transmission medium that would not support these capabilities or had connection bandwidths which were too slow to transmit high-fidelity voice or video.

Internet Providers

The site visit teams found that all but one Model Nets district had Internet access. The most common means of Internet access for Model Nets districts were local universities (49%), commercial providers (40%), and statewide networks (25%) (Figure 9). Eight districts relied on multiple Internet service providers, in the event that any one of the hosts proved unreliable because of excessive traffic or technical difficulties. Three school districts had their own Internet licenses, served as their own providers, and provided services to other entities for a fee. Generally, universities provided access free of charge through some kind of collaborative or reciprocal arrangement, which often involved the district serving as a test site for university research or the district agreeing to work with the university's preservice teachers. Other service providers included community "freenets," a local hospital, and a federal government agency.

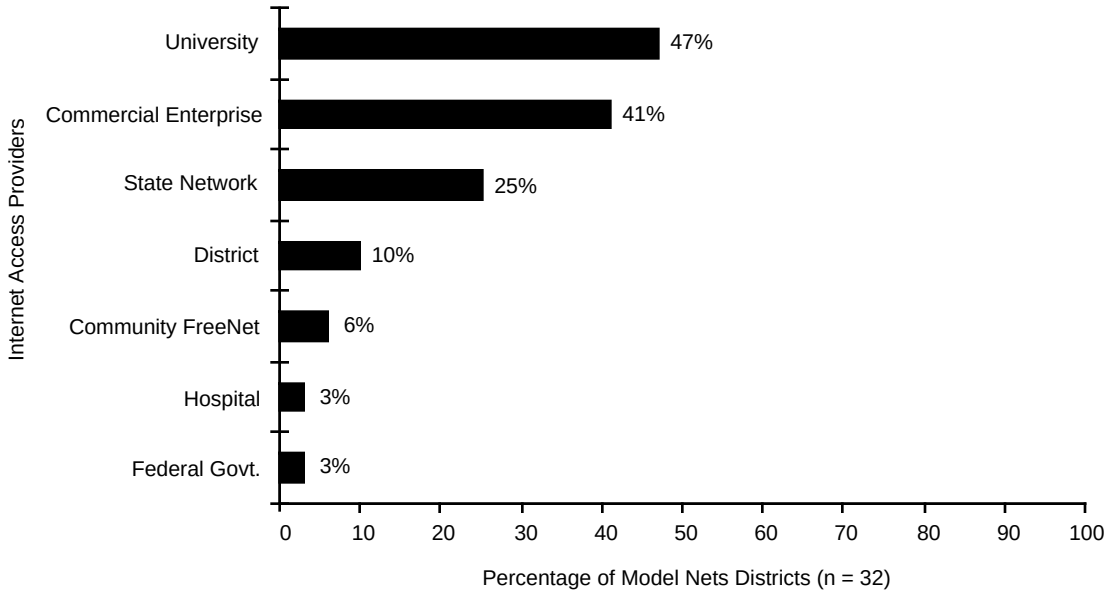

Figure 9. Internet Access Providers to Districts.

Management and Support

Seventy-eight percent of the districts had full-time district staff available on-call via e-mail or phone, while 66% had building coordinators available. For 60% of the districts, district staff and building staff shared responsibility for network maintenance and user support, according to the site visit reports. In one-fourth of the districts, the central office staff alone assumed responsibility for management, and in three districts building staff alone did. At one-third of the districts, students also performed troubleshooting of the networks and helped users solve problems. Roughly the same percentage of sites (31%) reported that vendors oversaw their network management, while to a lesser extent the district technology coordinator alone (28%), community volunteers (19%), classified staff (6%), or informal users' groups (3%) assumed roles in system management (Figure 10).

At the building level, only 25% of the districts had full-time network support staff. In lieu of full-time support personnel at the other 75% of the districts, building principals, secretaries, classroom teachers, and janitors often assumed network maintenance responsibilities in addition to their regular job responsibilities.

The site visit teams found that in districts where multiple levels of support were available, response to a call or problem was often dependent on the nature of the problem and the immediate availability of appropriate personnel.

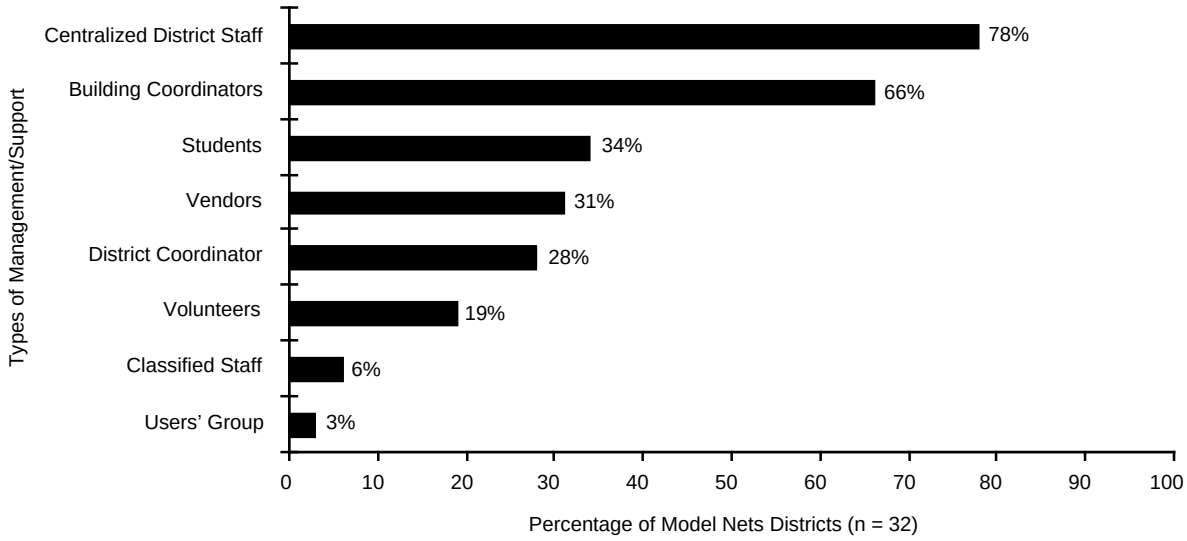

Figure 10. Network Management and Support.

Performance and Security

Very few teachers who responded to the teacher survey cited unreliable or slow network performance as a problem. However, according to the site visit reports, staff and students at 18 of the sites (56%) indicated that network performance problems had been substantial enough to interfere with planned instructional activities. Typical problems noted in the site visit reports related to lack of expertise in the initial technical design and the unreliability of network connections. Problems included

- incompatibility between wiring and peripherals, which caused the network to freeze;
- excessive traffic for the available bandwidth, which slowed network responsiveness; and
- difficulty connecting to hosts, which left instructional tasks incomplete.

According to the site visit reports, the greatest problems were associated with sites that had had connections for less than two years, sites that had recently made major upgrades to their networks, or sites that had experienced sudden, dramatic growth in network traffic.

Few districts mentioned any concerns related to network security. Typical precautionary measures included both physical security measures (for example, equipment lock-downs,

alarms on laboratory exits, supervision during use, etc.) and data security measures (for example, partitioning the network for different users, assigning user passwords, using software to restrict access to files and applications, etc.). A handful of districts indicated that they had experienced difficulties with students tampering with their systems. These breaches were often dealt with through appropriate-use policies that outlined consequences for abuse of privileges.

Teachers' Advice to Their Peers

When asked on the teacher survey what they would like to advise other teachers, some teachers gave advice on technical infrastructure and technical support. The advice tended to emphasize the importance of expert design of the system, good equipment, adequate maintenance, and ample access. Below are some typical comments grouped by common theme.

Acquire the Appropriate Hardware and Software

- Get the right system for the school.
- Spend the extra money for reliable equipment.
- Demand input into choosing the appropriate software to be placed on the network. If teachers don't buy into this, it'll never get used.
- Make it flexible and easily accessible.

Obtain Expertise for Installation and Support

- Hire people who truly know what they are doing to get the thing operational.
- Networks need to be professionally installed.
- Hire or designate a network guru who can work full-time on school technology support and growth. It is worth the expense.
- Network maintenance is essential; having a technology coordinator is a must.

Budget for Maintenance and for Contingency Plans

- Be prepared for the system to crash when you need it most; always have back-up plans.
- Maintain adequate funds for repair of individual units in each room.

Provide Ample Access to the Network

- Give every teacher a computer in his or her room.
- Push for at least 10 computers per room.
- Have a server where you and the kids can store and access files from any machine on the network; have access to districtwide communication and the Internet.
- Make sure there are plenty of phone lines and modems.

- A direct connection is best. No modems.
- Fiber optic cable is best.
- Software is needed in abundance.
- Everyone in the building must be on-line for computer networking to be successful.

Policy

Vision and Implementation

We gathered data on districts' visions of computer networks and the elements of those visions primarily through the site visit interviews, focus groups, observations, and document reviews. We found that visions ranged widely among the districts. Often, we found that a district's vision was, in fact, a description of the district's current network and its uses. Thus, our reporting of vision reflects this mix of vision and description of existing network implementation.

Three districts had no vision statements. Two districts had similar visions of transforming education, with references to dramatic changes in school structures, schedules, and the very notion of the place called school. One site that described itself as a "virtual school" allowed participants at multiple locations to work together and to share information. Another had a vision that redefined "customer served" to include learners of all ages.

As we observed the districts, several different elements of computer networking vision emerged. Some districts embraced more than one of these elements in their vision statements. The most common vision element was related to administrative efficiency and the smooth operations of the schools, which generally translated to staff seamlessly submitting and retrieving student and financial data.

Cited nearly as frequently was the desire to reform education by adopting practices to support students in using networks to gather, analyze, and communicate information needed for projects concerned with solving real-world problems. In this reform view, networks were cited as tools for learning, with teachers helping students understand what they did not know, find and access this information, analyze and synthesize the information, and then organize the information for specific audiences. Because networking was a tool for accomplishing these ends, it was not a curriculum area per se, and there were no computer literacy courses offered. Shared information bases, communications with peers, gateways to the outside world for students and others in the community, and increased teaching flexibility and resources were noted as parts of the vision at almost two-thirds of the sites.

Over half of the districts were concerned with ensuring that all students had equitable access to resources. Some districts were concerned with improving learning efficiency by individualizing instruction, exposing students to varied instructional strategies, and appealing to their "multiple intelligences" or learning styles. Many of the districts that had endorsed

this vision were particularly enthusiastic about integrated learning systems for providing individualized instruction along with a detailed assessment of each student's performance.

When asked about their visions, many sites also expressed the desire to enhance teachers' professional development, prepare students for the future workforce, and increase academic achievement.

Providing basic computer literacy (for example, keyboarding, programming, etc.) was cited by two districts, as was the desire to increase students' motivation by keeping them in school, exciting them about the learning process, or appealing to them with the same technologies popularized by the entertainment industry.

Decision Making

Although Model Nets did not set out to examine decision making as a component of computer network use, our review of the site visit data revealed that three-fourths of the sites had developed, or were in the process of developing, shared leadership between district central offices and individual school sites. Three of the sites were overseen by a committee typically composed of administration, a few teacher leaders, external business partners, vendors, and community members. Two districts had site-based management where the decision making was taking place at the building level. These districts failed to develop methods or strategies for equitably sharing resources among multiple school buildings and thus were failing to use individual and group strengths.

The majority of the sites pointed to administrators or technology coordinators at either the district or building level who had been instrumental in galvanizing support for the networks. These individuals played key roles in lobbying for support of the vision, in fundraising, and in identifying resources. However, at the three sites where a single leader, usually the superintendent, was the primary visionary, teachers indicated that they felt left out of the decision making process. Teachers at those sites expressed frustration over the lack of information shared with them about long-range vision, goals, plans, implementation activities, and timelines.

Most teachers responding to the teacher survey reported that their school administrations were supportive of networking in several ways. For example, three-fourths (77%) of the respondents said their schools helped provide professional development opportunities; nearly as many (71%) said the administration provided hardware and software. Almost two-thirds (63%) said the administration connected classrooms to the network. Another 60% said the school administration supported using the network for professional purposes.

Planning Processes

The site visits found that two thirds of the districts had written network technology plans and solicited broad-based input for these plans. Those districts that had a written plan tended to have input from stakeholders and to seek funding through grants. Staff in some districts said that the lack of a written plan ensured that they would remain more flexible and adaptable to

change, while staff in other districts said that the absence of a written plan was a failure to commit to a course of action, according to the site visit reports. On the teacher survey, less than half (43%) said any teachers were involved in developing the plan, and very few (15%) said they themselves had been involved in its development. The site visit teams found that opinions differed on the value of written plans. About one-fifth of the districts conducted regular needs assessments before planning. The relatively low incidence of evaluation plans found during the site visits was confirmed by the 13% who reported on the teacher survey that the use of networking technology at their school is evaluated.

When asked on the teacher survey what they would like to advise other teachers, some teachers commented on the planning process, as paraphrased below:

- Decide your goal ahead of time and keep evaluating new options in terms of whether or not they advance you toward your goal. Expect to be in this for the long haul, and set long-range expectations.
- Know what you want to accomplish before a network is designed, who will be responsible for management, and what money is available for additional hardware and connection fees.
- Plan carefully all aspects of networking. We have put a lot of time, planning, and thought into our tech plan. We will be on-line in August and have ample staff development opportunities to manage the level of frustration by making sure our people are comfortable.
- Require a plan for implementation in every classroom.
- Don't jump in and buy; first insist on an analysis and needs assessment. Don't expect all you are promised.
- Set goals to reach each year rather than trying everything at once.
- See other networking schools for ideas and insight.
- Involve students and the community.
- Enlist your most enthusiastic participants first. Put other programs on the back burner for a while. Focus on networking; don't overburden teachers with too many other curriculum changes at the same time.

Influence of State and Federal Policies

The site visits found that districts credited state policies with having more influence on their networking efforts than federal policies. Policies that were reported to have had positive impacts were those that helped the district expand its efforts through the purchase of infrastructure capability or by providing support for initiatives. Types of influential state policies included one state's reform act, which promoted the use of portfolio-based assessment of students. One district felt that this had paved the way for teachers to incorporate electronic portfolios into their instruction. Another state established a policy

providing low-interest loans to districts for technology purchases, and a second state provided funds for refurbishing older facilities to upgrade them for modern telecommunications wiring. Still other states promoted the exchange of electronic data and the development of annual school goals.

Policies that were reported to have had negative impacts were rooted in funding formulas that were perceived to be inequitable or arbitrary. Several districts commented that the state funding formulas favoring sites that had yet to establish networks placed early innovators at a disadvantage when they were looking for ways to expand their networking projects. A number of sites expressed concern about federal policies and the instability of federal funding. They said they feared that federal policies, which initially promoted networking through major grants and legislation, might veer in the opposite direction. They expressed concern that they would make major infrastructure investments with the expectation that they would be able to link to a "national information infrastructure" that might never materialize. They also cited repeated changes in federal entitlement programs as evidence of this instability.

School and District Policies

In the site visits, policies governing acceptable use were the most frequently identified policies. They dealt with topics such as accessing inappropriate materials (for example, pornography), using inappropriate language, and violating copyright laws. In the teacher survey, 46% of the teachers surveyed said their schools actually implemented or enforced acceptable use policies. Some sites anticipated concerns and issues by developing policies and integrating the policies into user training before encountering problems. On the other hand, many districts had not developed policies describing consequences for abuse of privileges. For example, some districts required users to sign contracts that outlined rules of appropriate use, but these contracts did not always specify penalties for abuse or the penalties were vague, except for instances in which they specified "loss of privileges." Additionally, districts often developed formal policies in response to specific issues that arose.

The next most common policies addressed common standards and expectations for purchasing, for user training, and for network access and overall use. Some of the policies aimed to establish uniform expectations for all sites within a district, including

- districtwide purchasing standards for hardware, software, and/or wiring;
- requirements for teacher professional development;
- schedules for phased implementation based on need, grade level, or model programs;
- requirements for administrative data exchange by staff;
- requirements for curricular integration and lesson plan development by staff;
- requirements for vendor relations and contract negotiations; and
- requirements for equitable access to the network for all students.

Other common policy types were geared to establishing rules of network use, including

- regulations on which users had priority for use of the network and under what circumstances,
- requirements for training of all users before accounts were issued,
- requirements that an adult be on hand to supervise all on-line activities,
- criteria for blocking inappropriate materials using networked software,
- prohibitions against engaging in multiuser dungeons (MUDs) and similar activities during school hours, and
- prohibitions against using disks brought from home (a measure intended to protect hard drives from imported viruses).

Several interesting examples of policies are discussed below.

Purchasing, Vendor Relations, and Phased Implementation. Common standards for districtwide purchasing, vendor relations, and phased implementation generally ensured compatibility among equipment and software. They also enabled larger districts to benefit from economies of scale.

Staff Professional Development. Professional development policies were generally related to scheduling, use of inservice days, or provisions for teacher release time. To address the issue of providing training before teachers used the network, one school district was contemplating petitioning its state education agency for a waiver to begin school 30 days early and to use this time for professional development of staff. To accommodate teacher release time, another school district had trained a pool of substitute teachers in network use and integration. These substitutes were on call both for emergencies and for planned professional release days. Yet another district created a "time bank." It added 10 minutes to each instructional day and then used this extra time to create 10 release days devoted to planning and professional development.

Student Access and Curricular Integration. One school district had a minimum number of minutes that each pupil was to spend on the network each week. At a site wishing to address curricular integration, teachers were expected to create lesson plans, then share them electronically with one another.

Some districts gave certain grades or classes of students priority in using the network. In other districts, policies gave priority to students completing required class assignments over students playing recreational games. Adult supervision and screening software were both intended to avert inappropriate network use. And the prohibition against engaging in MUDs and similar activities during school hours prevented students from monopolizing bandwidth needed for educational applications.

When asked on the teacher survey what they would like to advise other teachers, some teachers commented on policy, suggesting that districts establish rules and regulations for

network use, address security problems, and establish procedures *above the building level* to deal with "red tape."

Student Access Strategies

During the site visits we found that the majority of districts had one or more strategies to provide students with network access. To ensure that every student had some exposure to networking technology before graduation, half the districts were striving to integrate networking technology throughout their curricula. Other strategies to ensure access included providing students with permission to use the network during school hours as needed, particularly during free periods (for example, lunch, study hall, homeroom advisory periods, etc.). Some districts extended hours for school labs to accommodate students before and after school, often until 9:00 p.m. Some districts relied on students' exposure through specific elective or nonelective courses. More than one-quarter of the districts provided local dial-up modem access to their networks after hours.

Still other sites were experimenting with extending access outside of schools through equipment loans and checkouts and after-school networking clubs. One district had established four neighborhood homework centers and gave students, tutors, and parents dial-up modem access to the district's bulletin board. Other districts required that all students take a particular class designed to introduce them to network basics before graduation. These classes often concentrated on media literacy and research skills, and they were generally designed for students in their first or last year of elementary, middle, or high school.

Funding

Most of the districts depended upon an array of different sources of funds to cover the costs of school networking, including working with their existing capital and operating budgets, according to the site visits. Some of the districts were facing severe austerity budgets. All districts relied on two or more sources of funding and were applying a number of creative strategies to maximize their investments, including participation in beta test projects, resale of Internet services, and installation of networks in older facilities by using capital funds earmarked for remodeling. One school reported receiving a sizable donation from an alumnus who happened upon the school's World Wide Web site.

Federal sources cited by districts included programs in the Department of Education, Department of Energy, National Science Foundation, Department of Commerce, NASA, and other federal agencies. School fundraising (for example, PTO activities) continued to be an important means for many schools to generate revenues.

When asked on the teacher survey what they would like to advise other teachers, some teachers commented on strategies related to budgets and priorities, as paraphrased below:

- Save your money and implement all at one time, if possible. Wire for future expansion.
- Get the computers to the teachers first, then to students. Put computers in each classroom first, then a lab.

- Give employee discounts for home computers.

Evaluation

During the site visits, nearly half of the administrators or technology coordinators indicated that they had no immediate plans to evaluate their networks. In the teacher surveys, only 13% of the teachers reported that use of networking technology at their schools was evaluated. Among the reasons cited were the following:

- There was no pressing demand for such evaluation.
- The site managers felt that traditional evaluation measures would be of little use.
- The site managers had no models for developing meaningful evaluation measures.

Teaching and Learning

Extent of Teacher and Student Use

Median teacher use of computer networks was three hours per week, and one-third of the teachers surveyed reported that they used networking more than five hours per week, according to the teacher survey. Forty percent of the teachers surveyed also said that their students used networks in their classroom. Of these teachers, just under half said their students used a network on a daily basis, one-quarter reported weekly student use, and the remaining quarter reported less frequent student use.

On the teacher survey, significantly fewer high school teachers than elementary or middle school teachers said their students used networking technology. At two-thirds of the sites, network use by teachers and students was minimal (fewer than 10% of teachers or students were regular users) or moderate (less than 25% of the teachers and students were regular users). Several sites reported that their staff and students used the network daily for routine uses (such as checking announcements, responding to e-mail, managing files, etc.).

Types of Teacher Uses

Teachers who responded to the survey said they used networking technology in several ways (Figure 11). About half the teachers said they used it to conduct library or literature searches and communicate with colleagues in their district. Twenty-four percent communicate with district colleagues by network on a daily basis. Other common uses (by 30-42% of teachers) were to access databases for educational purposes, explore the Internet, communicate with colleagues outside their districts, and report student information. Fourteen percent of the teachers said they used networks to report student data daily. Less common uses of networking were following bulletin boards or newsgroups, communicating with universities and other organizations, transferring files (for example, FTP), gaining remote access to another computer (for example, Telnet), and participating in on-line discussion groups.

Very few teachers (12%) said they used a network to communicate with parents; however, 108 teachers across the country reported on the survey that they used it to communicate with parents at least monthly. These teachers were not concentrated in any one district; rather, they were scattered throughout a number of different districts.

Uses of Computer Networks	% of Teachers*
Conduct library or literature searches	51
Communicate with colleagues within district	49
Access databases for educational purposes	42
Explore the Internet	42
Report student information (grades, attendance, etc.)	31
Communicate with colleagues outside district	30
Follow bulletin boards or newsgroups	28
Communicate with universities and other organizations	27
Transfer files	26
Gain remote access to another computer	20
Participate in on-line discussions	20
Communicate with parents	12
* Percent based on 1,374 teachers who responded to the survey	

Figure 11. Survey Responses about Use of Computer Networks by Teachers.

According to site visit reports, 10 of the 13 most frequently reported teacher uses of networking involved LAN functions:

- Accessing productivity software (for example, word processing, databases, and spreadsheets)
- Storing and retrieving files
- Retrieving and submitting student data
- Interacting with administrators
- Managing student grades and work (for example, homework, tests, portfolios, etc.)
- Setting up meetings and schedules (for example, student course schedules)
- Submitting purchase orders and budget requests
- Distributing school news
- Sending memos and announcements
- Planning lessons with colleagues

According to the site visit reports, all but one district reported teachers using the Internet to access teaching resources (for example, background information for class preparation, lesson plans, etc.), and half of the districts said that members of their staffs participated in on-line discussion groups or listservs.

Other uses were less frequently reported by site visit teams:

- Interacting with students one-on-one
- Publishing academic or personal information on the World Wide Web
- Interacting with parents
- Coordinating extracurricular programs
- Assessing student understanding
- Participating in on-line courses
- Interacting with groups of students
- Submitting lesson plans from home for substitutes

Access to the Network

According to site visit reports, all of the districts in the study provided network access to teachers and administrators, though there were occasionally restrictions related to the number of hours of advance training required, the total number of available accounts, or available points of access. Twenty-six sites (81%) had policies permitting students to access the network directly. Six of the sites (19%) provided indirect access to students through teacher accounts.

Seventy-nine percent (or 1,048) of the teachers who returned surveys (1,374 total) had a computer in the classroom, and of these, two-thirds of the teachers (617 teachers or 67%) reported that they had classroom access to a LAN and/or a WAN. Only about one-fourth (24%) of the teachers with computers in their classrooms, however, said that they had a classroom modem. Seventy-seven percent of the teachers said they had used a network, 20% said they had never used a network, and the remaining 3% failed to answer the question. About half (52%) currently have electronic mail addresses.

According to the survey, roughly one-third (31%) of the teachers who provided an estimate of how often they used a network reported that they used it an hour or less per week; 39% used it 2-5 hours per week; 22% used it 6-20 hours; and 8% said they used it over 20 hours per week. The most common response, provided by one-fourth of the teachers who answered this question, was 1 hour per week. The median response was 3 hours per week; the mean was 7 hours. Twenty-five percent of the teachers said they used the network for more than 1 hour a day on average.

Half (50%) of the teacher survey respondents indicated that they usually gained access to a network in the classroom, while one-fourth of them (25%) logged-on in a student computer lab. Less frequently used locations for accessing a network were the teacher's home (18%), the teacher's room at school (16%), and the school office (7%). (Note that some teachers gave more than one location, so percentages do not equal 100%.)

About half (51%) the teachers reported on the survey that they used the network after school; slightly fewer teachers (43-45%) used networks during breaks and before school; 32% said they used a network during class time. Approximately one-fourth (24%) said they used a network during the evenings or on weekends. (Note that some teachers gave more than one time for network access, so percentages do not equal 100%.)

Teachers who responded to an open-ended question about future use of networking by students tended to suggest using it to communicate with others (for example, students in other states) or to access more resources for research. They indicated that they were interested in having students use the networks increasingly for educational rather than recreational uses and not simply for surfing but for deeper, more consistent purposes (for example, to develop and refine search strategies).

According to the site visit reports, more than one-fourth (28%) of the school districts permitted local community members to use their networks. Typical users included senior citizens, preservice and inservice teachers affiliated with local colleges, staff from neighboring school districts, and adults attending night courses. One-fifth of the sites also permitted classified staff (for example, support staff such as maintenance and cafeteria workers) to use the networks for personal or professional purposes.

Student Uses of Computer Networks

Approximately 40% of the teachers who responded to the survey reported that their students used networking technology in their classrooms. Of these teachers, 46% said their students used a network on a daily basis; 26% used it weekly; 11% used it monthly; and 17% used it occasionally during the year.

Of teachers who responded to the survey, fewer high school teachers (29%) than middle school (43%) or elementary school teachers (46%) said their students used networking technology in their classrooms.[2]

According to teachers, the majority of students (57-70%) using networking technology in classrooms do so to gain access to information from encyclopedias, library or literature searches, or other databases (Figure 12). Over one-third of the teachers said their students also used networks to communicate with teachers and to explore the Internet (39%). Some teachers (23%-31%) reported that their students used networking technology for other reasons: communicating within or outside the district, transferring files, remotely accessing another computer, communicating with universities and/or businesses, participating in on-line discussions or bulletin boards, and following bulletin boards or newsgroups.

[2] According to Pearson Chi Square analysis, these differences are significant at the $p<.001$ level.

Uses in the Classroom	% of Teachers Reporting Student Use*
Accessing encyclopedias	70
Conducting library or literature searches	67
Accessing databases	57
Exploring the Internet	39
Communicating with teachers	34
Communicating with students within district	31
Communicating with students outside district	30
Transferring files	29
Remotely accessing another computer	29
Communicating with universities, business	27
Participating in on-line discussions	23
Following bulletin boards or newsgroups	23
*Percent based on number of teachers who answered each question, ranging from 528 to 572.	

Figure 12. Student Use of Networking Technology in the Classroom.

Site visit teams reported that students at all the districts used LANs for searching on-line encyclopedias and databases, which were generally resident on CD-ROMs, and the vast majority of sites (90%) used the networks to access productivity software. Networked CDs and software applications enabled multiple users at multiple locations throughout a school building to access these resources simultaneously, thereby substantially reducing user frustration.

Other LAN uses found by the site visit teams included

- storing and retrieving files;
- producing publications, for example, school newspapers or yearbooks;
- looking up information on colleges and career options;
- creating multimedia products, including slide shows, interactive books or CDs, and TV broadcasts;
- interacting with teachers, such as turning in assignments electronically or holding electronic conferences;
- composing music;
- practicing skills using integrated learning systems; and
- working with computer-aided drafting and manufacturing (CAD/CAM) systems.

Students at the majority of districts used a greater variety of WAN applications than their teachers, according to the site visit reports. Typical WAN applications included

- Internet-based information searches;
- electronic mail with friends, relatives, and keypals;

- collaborative problem-solving projects with remote sites;
- creation of World Wide Web home pages;
- collections and analyses of data sets;
- electronic chats; and
- MUDs and multiuser shared experiences (MUSEs).

A special subcategory of electronic mail and chats in the site visit reports from five of the districts was foreign language exchanges, where students practiced their language skills with native speakers. Students were more frequently involved than teachers in designing and publishing World Wide Web home pages, and at three of the sites (9%), the activity was actually a commercial enterprise, with students advertising their skills to local community organizations.

Three districts mentioned information scavenger hunts as prominent activities in their programs and, where hunts were mentioned, they were generally introductory activities, according to the site visit reports. One site mentioned that students were using the network to compile college entrance portfolios and complete and send their applications packets electronically. In one of the site visit focus groups, teachers complained that students would find resources on the network, but the teachers were skeptical that these were accurate or reliable. They were also worried about student plagiarism.

Teachers who responded to an open-ended question on the survey about desired future use of networking by students tended to suggest using it to communicate with others (23%), for example, through on-line discussions and e-mail; to access more resources for research (23%), for example, through the Internet, World Wide Web, and networked CD-ROMs; and to use the Internet in general (13%). Typical comments included the following:

- Use the net more to work with students in other states.
- Use pen pals.
- Find mentors to help students with their studies.
- Put student work on the net, solicit comments and criticism, and do collaborative work.
- Use the net to find information for assignments.
- Develop and gain search strategies by using the Internet.
- Share interdisciplinary unit discoveries with other students.
- Make net use more educational. Allow fewer games.
- Use the net more consistently and more deeply. Don’t limit net use to surfing.

Impact on Teachers

Teachers who responded to the survey reported that the use of networking technology had an overall positive impact on their professional lives (Figure 13). The majority of respondents said it had increased their comfort with technology in general, the materials and resources they can use in their classes, their communication with colleagues, the overall quality of their teaching, and their job efficiency. Almost half (47-49%) felt it increased their enthusiasm for teaching and their interest in the subjects they teach. Over 40% of the teachers who responded to these items said that it increased their repertoire of teaching strategies and their content knowledge. In each of these areas, nearly all those teachers who did not see a positive impact at least said there had been no impact, rather than a negative one.

Teachers were asked on the survey to use a 10-point scale to reflect how they would feel if their networking connection were eliminated. A rating of 1 was defined as "happy, relieved," and 10 was defined as "sad, angry, frustrated." About 75% of the teachers surveyed answered this question. Ninety percent of those who answered were within a range of 6 to 10, and one-third responded with a 10, indicating that a large majority would regret losing this resource.

Areas of Effect	% of Teachers Reporting Positive Effects*
Increased comfort with technology in general	78
Increased materials and resources to use in class	67
Increased communications with colleagues	63
Increased overall quality of my teaching	55
Increased job efficiency	54
Increased enthusiasm for teaching in general	49
Increased content knowledge in subjects taught	49
Increased interest in subjects taught	42
Increased repertoire of teaching strategies	42
Increased time spent in professional development	37
Increased repertoire of student assessment strategies	34
Decreased sense of classroom isolation	29
Decreased time spent on administrative tasks	29
Decreased overall workload	20
Decreased time spent in meetings	18

*Percent based on teachers who responded to these items, where the number of teachers ranged from 856 to 908. "Positive effects" was defined for the top 11 items in the table as a response of 4 or 5 on a 5-point scale where 1 = decreased very much, 3 = no effect, 5 = increased very much. For the bottom 4 items, a "positive effect" was defined as a decrease, i.e., a rating of 1 or 2.

Figure 13. Teachers' Reports of Networking Effects on Their Professional Lives.

Comparisons of elementary, middle, and high school teachers found that middle school teachers who responded to the survey tended to report a somewhat more significant impact of networking technology on their professional lives than did high school teachers. For example, middle school teachers said it increased their job efficiency, subject matter knowledge and interest, repertoire of teaching and assessment strategies, resources for class,

comfort with technology, enthusiasm for teaching, and overall quality of their teaching significantly more than high school teachers did. Elementary teachers said it improved the quality of their teaching and their comfort with technology significantly more than even the middle school teachers. The elementary teachers also reported (more frequently than even the middle school teachers) that networking reduced their time spent in meetings.[3]

Site visit reports tended to corroborate these impacts reported on the survey. Site visit data suggested that networking appeared to impact teachers in three fundamental ways: their organizational efficiency, productivity, and sense of professionalism. The single most frequently observed impact, noted in half the districts, was increased communication among staff. Next most frequent, at just under half of the districts, was a shift among teachers from the role of information-provider to facilitator of student learning.

At over one-third of the sites, staff reported increased choices in selecting resources and instructional strategies and increased enthusiasm for their work, two elements also mentioned in the survey responses. Related to this, in just under one-third of the site visit reports, teachers commented that they felt more a part of the professional community.

Other common areas of impact found both by site visit teams and on teacher surveys were related to increased ease and efficiency of work performed. These included reports of fewer and more efficient face-to-face meetings (both team and whole faculty meetings and parent-teacher conferences). Staff reported that decisions were made more rapidly because input and feedback were more immediate, according to the site visit reports.

Several districts reported to site visit teams that it was easier to manage student work, including homework assignments and portfolio contributions. Staff mentioned that the network saved space that otherwise would have been occupied by filing cabinets and boxes, and the network made it easier for a greater number of people to access, manipulate, and compare student work.

Although less frequently mentioned in site visit reports, other areas of impact included reducing

- student behavioral problems;
- class interruptions;
- teachers' sense of classroom isolation; and
- teachers' use of noninteractive audiovisual materials—for example, videos, films, etc.

Isolated reports of impact, each mentioned in only one site visit report, included increases in

- teachers' ability to locate needed information or materials,
- teachers' overall workload,

[3] Comparisons were 1-way ANOVAs, with $p<.05$ on all.

- teacher self-esteem,
- teacher use of research in planning lessons,
- student-teacher interaction,
- teacher work at home, and
- teacher burnout.

Impact on Classroom Practice

Of those teachers whose students used networking technology in the classroom, the majority reported that the availability of such technology influenced their teaching in several ways. In both site visit reports and survey responses, teachers credited computer networks with helping students develop new skills and with increasing student motivation. A review of the survey data also found teachers commenting on greater efficiency in teaching and learning and increased academic achievement by students because of computer networking. Students in focus groups corroborated some of these findings. Several survey questions elicited teachers' responses that indicated a declining impact of networking as the grade-level taught increased. Thus, the highest impact was reported by elementary teachers, lower impact was reported by middle school teachers, and the least impact was reported by high school teachers. These findings and others are discussed in the following paragraphs.

Nearly three-fourths of the teacher respondents cited increased attention to students' skills in locating and accessing information (Figure 14). Approximately two-thirds of these teachers said they had observed an increase in the amount of independent work done by students. Also, over half of the teachers reporting positive changes in teaching said that networking technology in the classroom increased the quantity and types of student writing, links between classroom assignments and the real world, the focus on critical thinking skills, the use of small cooperative groups, the use of complex or interdisciplinary projects, and the quantity or type of reading exhibited. Site visit teams reported that students in focus groups indicated their work seemed more real and that they were able to increasingly choose different formats or different modes of communicating their knowledge and skills to others.

One-third or more of the teachers responding to the survey said the availability of networking technology in their classrooms led to more one-on-one time with students, more or different types of math analysis and science investigation assignments, and a wider range of classroom assessment strategies. Less than 1% of teachers noted any negative impact of networking technology on their teaching in the areas queried.

Networking Led to an Increase in These Aspects of Teaching	% of Teachers Reporting Positive Changes in Teaching*
Attention to skills of locating and accessing information	72
Student independent work	68
Quantity or types of writing	56
Links of classroom assignments to the "real world"	54
Focus on critical thinking skills	54
Use of small cooperative groups	53
Emphasis on depth versus breadth of knowledge	52
Use of complex or interdisciplinary projects	51
Quantity or types of reading	51
Time spent one-on-one with students	44
Quantity or types of math analyses	40
Quantity or types of science investigations	37
Use of assessment strategies	34
Linking of classroom assignments to district, state, or national standards	26
*Percent is based on number of teachers who responded to these items on the survey, which ranged from 551 to 602. "Increase" was defined as a response of 4 or 5 on a 5-point scale where 1 = decreased very much, 3 = no effect, 5 = increased very much, 2 and 4 = undefined.	

Figure 14. Impact of Computer Networks on Classroom Practice.

Well over three-quarters of the sites reported increased student interest and motivation with respect to school in general, according to site visit data. Students in our focus groups commented on faster and easier access to information that they needed and access to a greater variety of information resources. Students and teachers both noted that this ease of access resulted in better writing and presentations, broader scope and improved organization of ideas in research, and the ability to work more quickly and efficiently to complete projects.

About one-fourth of the districts reported enhanced computer skills among students, according to site visit data. Roughly the same number of sites noted that students spent more time in school on work and that they displayed increased pride in their work. Some districts reported that students spent more time out of school on work, were more productive, and improved their grades as a consequence of their network access.

Less frequently reported impacts included increased

- student control and choice,
- use of student-produced materials in instruction,
- class and school attendance,
- media literacy,
- student maturity and consideration for others, and
- student apprenticeships.

Comparisons across teacher responses to the survey at elementary, middle, and high school levels revealed that elementary and middle school teachers tended to report greater impact on their students than did high school teachers for many of the variables queried. For example, elementary teachers reported an increase in the following practices that was significantly greater than that reported by high school teachers: letting students work independently, working one-on-one with students, using cooperative groups, focusing on critical thinking and information-locating skills, and the quantity or type of writing and math. Middle school teachers reported an increase in the following practices that was significantly greater than the increase reported by high school teachers: emphasis on depth versus breadth of knowledge, complex or interdisciplinary projects, and linking classroom assignments to the real world and to standards.[4]

Other Important Changes in Teaching and Learning

Many teachers also responded to an open-ended survey question about other important ways teaching or learning had changed in their classrooms because of networking technology. Thirty-one percent of those who commented noted improvements in some aspect of instructional methods and efficiency or student knowledge and engagement.

Fourteen percent noted changes in instructional methods, as evidenced by the following quotes:

- I'm able to teach information skills to much younger students.
- More peer teaching is occurring at computers.
- Use of resources now extends beyond the classroom.
- I see more use of multimedia.
- Teaching and learning have become a collaborative effort beyond the walls of the classroom and building.

A few other teachers made comments about increased efficiency in teaching and learning because of computer networking use, as follows:

- Research for projects has improved so that more time can be spent on higher levels of thinking.
- Improved students' organization-of-time skills when networking is used along with labs and other activities in classroom.
- More immediate feedback is available for grading.
- Networking allows more emphasis on quick access to information—laser discs, VCRs, etc.

[4] Comparisons were 1-way ANOVAs, with $p<.05$ on all.

- There is a direct link to all others in the building. I can communicate with the office or other teachers about students without leaving the students.
- Students are forced to be more productive. They have lost several excuses for not completing their work.

Twelve percent of teachers who answered this question noted changes in student initiative and motivation, as illustrated by these comments:

- Students are more independent and responsible about doing their work.
- Students work together, take charge.
- Students are more enthusiastic about researching.
- Students are more empowered.
- Students are more interested in discussing real world events.
- The younger children want to write more and more.

A few other teachers noted specific changes in student knowledge or achievement and attributed these changes to using networking technology:

- Students produce finished products even the slowest learners can be proud of.
- Student output is more creative. Young students are more informed about real world events.
- Use of the Internet has increased communication skills; students are becoming more global learners.
- Children's stories are more complex and filled with details.
- More in-depth questioning is occurring, including more reflection by kids and more probing questions, mostly through knowledge building with our program.
- Much more writing and quality writing is taking place.

When asked on the teacher survey how they would like to advise other teachers, some teachers commented on teaching and learning. One-fourth of the teachers in a sample of those who responded to this question volunteered comments on the values of computer networking for teachers and students. While their comments were quite supportive, some seemed to imply that many teachers might feel reluctant to become involved in new technology, perhaps based on experiences at their own schools. Typical comments were as follows:

- It's the best thing to happen in education in years.
- It's easy to use. It provides access to a wealth of information and motivates learning for both teacher and student.
- Use it, and you'll learn to love it.

- Have patience and a sense of humor; there's a great payoff.
- Be open-minded. Give it a try; get involved.
- Don't be afraid of making mistakes.
- It's good for sharing research techniques and data.
- It creates tremendous opportunities for integrating subject matter and communicating with others. Students are very enthused about learning.

Other comments on the survey related specifically to classroom integration strategies:

- Don't be afraid to let students explore.
- Begin with a basic overview of using it. Don't just turn students loose.
- Keep class sizes small; maintain a balance of technical and nontechnical activities.
- Work with other teachers.
- Students' comfort level increases rapidly with daily use.
- E-mail is easy; learning to find specific information in a timely manner is more difficult.
- Take one step at a time—don't get frustrated if you don't have the answers to all your questions. Be courageous enough to play, explore, create.

Finally, some comments were related to specific advantages for teachers:

- It is enjoyable to talk to other professionals in your teaching area. Listservs are convenient. Communication is wonderful.
- It can really save time/paper and speed up communication with staff.
- It's great and interesting. It's very time-consuming. It's a great way to avoid mundane cleaning and organizing around your room.
- It increases, not decreases, your work hours. It is never going to be the best way to communicate important issues, but it is fun to be in contact with greater resources.
- You will be amazed at how the world will open up at your fingertips.
- It opens new possibilities; it forces a rethinking of who holds information and of one's whole role as a teacher.

Effects on Students

Teachers whose students used networking technology in the classroom tended to be quite positive about its effects on their students (Figure 15). About three-fourths said students increased their comfort with technology, their interest in school and particular topics, and their information access skills. About two-thirds of these teachers said that networking has had a positive impact on students' overall academic achievement and self-confidence, content knowledge, time engaged in learning, and use of resources. Half of these teachers

said it had a positive impact on students' comfort with telecommunications and ability to work cooperatively in teams. About 40% saw a positive impact on completion of assignments and communication among students. Fewer than half saw any positive impact on students' communication with peers, teachers, or organizations outside the school; on attendance; or on completion of assignments.

Areas of Impact	% of Teachers Reporting Positive Impact*
Comfort with technology in general	79
Interest in school	78
Skills in locating and accessing information	77
Interest in particular subjects or topics	76
Content knowledge	71
Number and quality of sources used in projects	66
Time engaged in learning	64
Self-confidence or esteem	64
Overall level of academic achievement	63
Ability to work in cooperative teams	52
Comfort with telecommunications	51
Communication with other students	42
Assignment completion	41
Communication with teachers	27
Communication with universities, businesses, etc.	19
Attendance	19
*Percent based on number of teachers who responded to these items on the survey, which ranged from 538 to 591. "Positive impact" was defined as a response of 4 or 5 on a 5-point scale where 1 = decreased very much, 3 = no effect, 5 = increased very much, 2 and 4 = undefined.	

Figure 15. Teacher Reports of Networking Impact on Students.

As noted previously, middle and elementary teachers tended to report significantly greater impact of networking technology than did high school teachers in our study. This was true for impact on students as well as impact on teachers. Elementary and middle school teachers said that networking had a significantly greater impact on their students' overall level of academic achievement, interest in school, content knowledge, time engaged in learning, and self-confidence or esteem. Middle school teachers said their students experienced the most impact in a few important areas: information-locating skills, number and quality of sources used, completion of assignments, and ability to work cooperatively in groups. Both middle and high school teachers reported significantly greater amounts of student communication with universities and businesses as a result of networking than was reported by elementary school teachers.[5]

[5] Comparisons were 1-way ANOVAs, with $p<.05$ on all.

When asked on the teacher survey what advice they would like to offer other teachers, some teachers commented specifically on how networking might benefit students:

- It adds another dimension to learning. Students' use of library resources increases drastically. Students are better prepared to meet expectations in the job market.
- It allows correspondence with other students and allows students to stay current on news, weather, and sports programs. Information is available beyond the encyclopedia.
- It helps students manage their assignments.
- It increases communication with students.

Impact on Schools

Nearly two-thirds or more of the teachers who responded to the set of survey questions on school impact felt that networking technology had a positive effect on schools in several ways: the overall quality of teaching, the overall level of student achievement, teachers' sharing of ideas and skills with others in the district, and the staff's sense of empowerment (Figure 16). Roughly half or more felt that it increased general staff morale, the effectiveness of school management and operations, and the school's relationship with the community. Forty-two percent said it improved relations with parents.

Increased presence of the community in the schools was the most prominent area related to school impact found in the site visit reports. At one elementary school, in fact, a senior citizen center was built within the school, and students were paired with seniors as their "network navigators," while the seniors volunteered to help with students' basic literacy skills. Other types of community presence included parents and business volunteers who helped run the network; electronic mentorships and apprenticeships, which often involved face-to-face meetings; and attendance at evening open labs and courses, where community members were encouraged to use the network for personal and professional purposes. Staff and students spoke very positively about the increased community involvement in schools, noting that it reinforced and validated their work.

Areas of Impact	% of Teachers Reporting Positive Impact*
Overall quality of teaching	70
Overall level of student achievement	67
Staff sharing ideas and skills with others in district	65
Staff sense of empowerment	65
General staff morale	61
Effectiveness of school management	58
Effectiveness of school operations	50
Relationship with community	49
Relationship with parents	41
*Percent based on number of teachers who responded to these items on the survey, which ranged from 563 to 600. "Positive impact" was defined as a response of 4 or 5 on a 5-point scale where 1 = decreased very much, 3 = no effect, 5 = increased very much, 2 and 4 = undefined.	

Figure 16. Impact of Networking on Schools.

On the teacher surveys, elementary and middle school teachers again tended to report greater impact of the network on their schools than did high school teachers. Teachers in the two lower levels reported that networking had a significant impact on general staff morale and sense of empowerment, on the sharing of ideas and skills, on the overall quality of teaching, and on the overall level of student achievement. The impact reported by high school teachers was not as great. Elementary teachers reported greater improvement than high school teachers in the effectiveness of their school management and in their school's relationship with parents.[6]

According to site visit reports, some districts were beginning to revise their curricula to integrate computer networks with teaching and learning. Cross-grade-level activities often involved students from higher grades teaching or mentoring students in low grades, either by introducing them to networking or multimedia production skills or by teaching specific topics which had been researched using the network. Frequently students reported using the network to send e-mail to one another and to exchange work and ideas. For example, older students e-mailed stories for younger students to illustrate.

Four sites were experimenting with virtual schools and conducting classes with remote sites engaged in common projects.

A few districts reported the following types of impact:

- Reduced paper costs
- Increased parent involvement
- Redesign of school facilities to accommodate network access

[6] All comparisons were 1-way ANOVAs, with $p<.05$ on all.

- Revised school schedules to accommodate network-based projects
- Reduced textbook expenditures
- Increased library circulation

Professional Development

Although we found a myriad of sources of training and a number of different training activities, most sites focused training strictly on the use of tools but not on integration with instruction. At sites that offered what teachers felt was ineffective professional development, training was one-shot; therefore, few teachers were actually using the networks. In these cases, teachers sometimes conducted student activities that had no direct connection to the curriculum (for example, net surfing without a purpose).

According to responses on the teacher survey and data on site visit reports, teachers obtained training in how to use networking technology from a variety of sources (Figure 17). The most commonly available and frequently used sources of training were self-teaching, colleagues, and the school technology coordinator.

Source of Training	Percent of Teachers Saying It Is Available	Percent of Teachers Who Used It	Mean Effectiveness Rating*
Self-taught	100	44	3.2
Colleagues	54	41	3.7
School technology coordinator	51	36	3.8
Conferences or workshops	37	24	3.5
District technology coordinator	39	22	3.5
Consultants	23	15	3.3
Students	17	11	3.5
Vendors	13	8	2.9
On-line	16	7	3.2
College courses	14	7	3.6
State provided	9	2	2.5
Regional or national organizations	9	2	3.0
Parents or community members	8	3	3.1

* Effectiveness is the mean on a 5-point scale, where 1 = not effective, 3 = effective, 5 = very effective, 2 and 4 = undefined.

Figure 17. Perceived Effectiveness of Training in Network Use.

Teachers felt that the most effective sources of training were the school technology coordinator and colleagues, followed by college courses, conferences, district technology coordinators, and students. Training sessions provided by state organizations, vendors, regional or national organizations, parents/community members, and on-line courses were less available, used less frequently, and rated less effective than other sources of training. Self-teaching, while available to all respondents and used by nearly half (44%), received a

lower effectiveness rating from teachers than several other strategies, though they still deemed it effective. Because effective professional development is so important with any major educational innovation, we made statistical comparisons of the selected sources of training to determine those which teachers felt were *significantly* better than others (ANOVAs with single factor repeated measure). Teachers indicated that training provided by school technology coordinators was significantly better than that provided by every other source mentioned on the survey, except colleagues (Figure 18). Teachers said their colleagues were more effective trainers than all other sources except school technology coordinators. They also felt that their own students were as effective as consultants.

	Colleagues	**School Techs**	**Students**
Self	Colleagues p<.0001 n=722	School techs p<.0001 n=576	Not significant
Colleagues		Not significant	
Conferences	Colleagues p<.0001 n=463	School techs p<.0001 n=404	Not significant
District Techs	Colleagues p<.0001 n=450	School techs p<.005 n=426	Not significant
Consultants	Colleagues p<.0001 n=316	School techs p<.0001 n=287	Not significant
Students	Colleagues p<.0001 n=264	School techs p<.0001 n=227	
Vendors	Colleagues p<.001 n=174	School techs p<.0001 n=160	Students p<.001 n=82
Note: The entries in the table are the sources of training rated significantly more effective of the pair compared. N is the number of teachers who rated both sources being compared.			

Figure 18. Comparisons of Effectiveness for Types of Training.

We found differences in faculty teaching at different grade levels with respect to the different sources of training used and valued. Elementary and middle school teachers used their colleagues, school technology coordinators, district technology coordinators, and consultants significantly more than did high school teachers.[7] Other than these differences, teachers reported that they used the various sources of training with about the same frequency across grade levels.

[7] 1-way ANOVAs, p<.001

There were no significant differences among teachers at different grade levels in their effectiveness ratings of different sources of training, with one exception: both middle and high school teachers said their students were more effective trainers than the elementary teachers indicated their students were.

The site visit teams reported that the majority of the sites made use of district and building coordinators to provide staff training on network use. But districts identified a number of different approaches to delivering professional development. At nearly three-quarters of the districts, informal training took place through peer-to-peer interchange. Just under one-third of the sites relied on universities to offer staff professional development. Nearly one-fifth of the sites tapped students, parents, or community volunteers to provide training, or staff were responsible for their own training. During site visits, vendors and others (state departments of education, national conferences, and classified staff) were least commonly mentioned as providers of network training.

At three-quarters of the sites, school-year inservice days and after school workshops were devoted to network training. One school district ran a three-day winter conference for staff. Another district devoted one day per month of common planning to networking uses. Additionally, half of the sites indicated that they planned summer institutes to familiarize staff with the network and to provide time for curriculum planning. In some districts, staff were paid for their time, and in others, teachers were asked to volunteer their time.

One-third of the sites offered on-demand or on-call training, generally from full-time, dedicated building or district staff. One large urban school district employed a cadre of master teachers who served as peer coaches. These teachers were available to take over classes and to model instructional strategies for incorporating networking technologies into classrooms. Another district used grant monies to hire a trainer to work one-on-one with any interested teacher.

Staff at one-fifth of the sites subscribed to listservs or used electronic mail to enhance their understanding and use of networking. This same percentage of sites encouraged teacher self-training by providing incentives for teachers to use computers at home. Incentive programs included low-interest loans, summer and evening equipment checkouts, and outright purchases of laptop computers for all staff. At several sites, custodians participated in the training, so they too received equipment to take home, and at two of these sites, the custodians became so adept at using the network that they provided training for teaching staff.

Additionally, one-fifth of the sites involved students in providing informal training for teachers. In some cases, an entire classroom of students and their teacher would receive training. In other cases, small cadres of interested students would be trained to serve as mentors. At one site, these students were each paired with a teacher to serve as a "network navigator" for the teacher, helping troubleshoot problems and find resources for specific topics the teacher was exploring in classes.

Other less frequently employed approaches documented in the site visit reports included

- university courses for credit,
- on-line courses,
- training offered during teacher prep periods to interested teachers,
- training offered simultaneously to teachers and students, and
- prepared notebooks with ideas, suggestions, and step-by-step instructions.

Four sites partnered with local universities to offer evening courses. One site had had such an arrangement for many years but indicated that it might discontinue these courses because the university lagged behind the school technologically and was therefore unable to provide useful training.

In response to the teacher survey question on what they would like to learn more about related to networking, teachers pointed to "skills" and logistics of use (for example, how to identify mentors or keypals for students using the Internet). When asked on the teacher survey what advice they would like to give other teachers, over 40% of the sample of teachers gave generic advice about training, such as "get knowledgeable training" and "teacher training is essential." Many also made more specific recommendations about the structure of good professional development, and they often suggested using peers and students for training and support. Illustrative examples of teachers' advice on staff development are grouped by common topics below.

- Staff development cannot be done in one-shot deals; follow-up and building support is crucial.
- Take slow steps integrated with multiple training sessions.
- Attend as many staff development classes as possible.
- Take adequate time up front on training.
- Get excellent trainers.
- Don't read the manuals; hire a technology person to read the manuals and help you.
- Take university classes.
- Don't be afraid to get the help of students.
- Be open to all people who have expertise—especially students.
- Use students as teachers. There are kids that love computers and know a lot about them; learn from those kids. They'll love to teach a teacher.
- Develop a group of colleagues that will use the network.
- Share what you are doing with others.

- Use the buddy system, so people can support each other.
- Be sure there are lots of sharing sessions in which teachers can tell how they are using networking.
- Be patient! Everyone will not be excited about it. They must find a use for it; you can't force them.

What Teachers Would Like to Learn More About

Among the open-ended questions asked on the survey was the question: "What uses of networking technology would you like to learn more about?" Teachers who answered this question tended to cite interest in learning about the Internet in general (30%), how to communicate with others (20%), how to access information and resources (16%), how to use the local computer network (15%), or "everything" (10%). The remaining 9% gave a variety of other responses.

Of those wanting to learn to communicate electronically, just under half did not specify whether the communication was to involve teachers or students and instead said they wanted to learn more about

- sending e-mail to other schools,
- following bulletin boards and on-line discussion groups, and
- sharing information with other classrooms.

About an equal number specifically mentioned they wanted to learn how to communicate with colleagues, saying they were interested in

- communicating with colleagues within the district and
- learning how to contact other teachers in schools outside the state for the exchange of student work.

One-fifth of those wanting to learn how to communicate electronically specifically wanted to learn to facilitate communication among their students. Their typical interests were either

- connecting students with other students or
- communicating with classrooms all over the world.

A few other respondents made singular comments, wanting to learn more about

- video conferences,
- home page production,
- how to adapt the curriculum more effectively for all levels of students, and
- "how my particular area could benefit" (from networking) and "what's out there" (on the Internet).

Barriers to Implementing Computer Networks

While site visit reports indicated that districts identified numerous barriers that they encountered and overcame, or that they continue to grapple with, during the site visits they repeatedly identified two primary barriers: funding and time to learn to use and to implement computer networks. Many of the other barriers cited, such as inadequate training, equipment, or materials, were often related to the fundamental obstacles of lack of time and money.

In the teacher survey, teachers cited relatively few obstacles to their using the network as much as they would like. Confirming the site visit findings, the most frequently cited obstacle in the teacher survey was "no time provided during the school day to use the network," with one-fourth of respondents indicating this was a problem. One-fifth of them said there was not enough training provided. Contrary to some expectations, unreliable or slow network performance, lack of technical support, inconvenient locations, and inconvenient access times were not problems for most teachers who responded to this survey. In each case, only 8-15% of teachers said these were issues. Findings from the site visit reports indicated there were a variety of problems related to network performance across the districts, but we have no evidence that these were considered major obstacles to teaching and learning.

Many of the teachers who responded to an open-ended question on the teacher survey about obstacles to using computer networks in classes reported limited access for students (48%). Comments by teachers and students to site visit teams indicated that lack of use was because of limited access or limited time during the school day and not because of limited interest. Other obstacles cited by a number of teachers were technical problems (13%), lack of planning time (13%), and lack of teacher knowledge (9%).

Those who cited limited access made comments such as

- not enough computers (most frequent comment),
- lack of phone lines and/or modems,
- software not updated,
- no lab coordinator, and
- "I am met with *hostility* when I try to arrange to take my classes to available labs."

Typical comments about technical problems were

- interface problems,
- maintenance of lab,
- software incompatibility between lab and classroom,
- slow speed of use, and
- "You never know when it will be down." (This was most frequent type of comment.)

Problems with lack of time were often expressed in ways such as

- need additional time with colleagues for team planning;
- not enough time for me to get on, to know the in's and out's, to plan; and
- not enough time to develop curriculum.

A few other teachers expressed unique problems, such as the following:

- Students work at such different rates.
- It's extremely hard to manage small group instruction during whole class lessons. Students miss instruction, and it must be repeated later for them.
- It's not a part of our required content.
- Bad press (for example, cyber-kidnapping).
- Students don't yet expect to use telecommunications in a ceramics class.
- There are no walls between classrooms.
- There are too many choices.

In the teacher survey, a few teachers expressed negative side effects of computer networking in four areas: workload, administrative tasks, isolation, and meeting time. While 20-30% of teachers reported positive effects of networking in these areas of their jobs and 51-73% of them reported "no change" in these areas, a few teachers nonetheless reported a negative experience. Of those who answered these items (nearly 900 teachers on average), 29% said networking increased their overall workload, 16% said it increased the time they spent on administrative tasks, 11% said it increased their sense of classroom isolation, and 10% said it increased the time they spent in meetings. Reports of negative side effects were dispersed lightly throughout the sample, not concentrated in a few districts. In a few districts, however, virtually all teachers felt that networking had positive effects, such as decreasing the time spent in meetings or training, decreasing their workload, and decreasing administrative tasks.

Poor network performance was one barrier cited by teachers at more than half of the participating sites, according to site visit reports. The most problems occurred at sites that had had connections for less than two years, at sites that had recently made major upgrades to their networks, or at sites that had experienced sudden, dramatic growth in network traffic. Staff and students both complained about frustratingly poor network performance. Teachers said they often had to abandon instructional plans when the network was "down."

Guidelines for Implementing Effective Computer Networks

We have created the Guidelines for Implementing Effective Computer Networks on the following pages to assist federal agencies as they develop criteria for awarding funds to school districts implementing networks. The guidelines are also intended to help school districts to plan and implement computer networks. We derived these guidelines, or characteristics of effective computer networking, based on our case studies of school districts, on teacher surveys, and on the expertise of a group of subject-matter specialists who reviewed the research results.

For the purposes of the guidelines, "effective practices" are defined as those characteristics of computer network implementation that support a model of learning in which students explore, discover, create, propose explanations and solutions, and take action on what they have learned. The guidelines are not intended as an all-inclusive or rigid set of requirements. We do not expect even an exemplary school district to demonstrate every effective practice in the guidelines. We also recognize that many districts that were not included in the Model Nets research have developed other effective practices not mentioned here.

We have organized the effective practices under the three domains of our study: technical infrastructure, policy, and teaching and learning.

Technical Infrastructure Characteristics and Practices

Infrastructure

1. The district provides convenient access to all users.
2. In a given school building, a single LAN supports video, voice, and data communications for both instructional use in all classrooms and administrative use.
3. In a given district, a single district-wide WAN supports video, voice, and data communications for both instructional and administrative uses.
4. The district WAN has multiple connections to the Internet.
5. The district provides users with dial-up access from home through external Internet service providers.

Security

1. Configuration-control software prevents users from "hacking" individual computers and thus rendering them incompatible with the network.
2. Proxy servers and firewall technology limit access to sensitive information, as appropriate.

Services

1. All students, teachers, staff, and administrators have e-mail and share a common, districtwide e-mail system, which may include bridges between subsystems.
2. A shared, standardized network infrastructure serves all facets of education, including administrative and teaching functions.
3. The network supports a wide range of functions, including e-mail, file sharing, printer sharing, conferencing, access to productivity software (e.g., data bases of student information), news groups, terminal connections, access to library databases and CD-ROM databases, access to the Internet and World Wide Web, security and climate-control systems, etc. (See Appendix E, Network Services.)

Support

1. A key server system provides centralized software distribution and configuration management.
2. Use of configuration control software (At Ease, FoolProof, etc.) helps support staff to maintain the network.

3. The district establishes baseline standards for hardware and software across the network to ensure compatibility and performance.
4. The district provides support in layers (for example, local or site level, district level over the network or by phone, and local visits).
    - The district builds a cadre of internal (school and district) experts.
    - The district provides on-site network managers at building level.
    - Students at high school provide "help desk" support to users and get vocational credit.

Policy and Implementation Characteristics and Practices

Vision, Leadership, and Decision Making

1. The vision of computer network use is integrated with teaching and learning and includes these components:
    - Universal access to the network by teachers and students
    - Network perceived as a tool
    - Improvement of instruction
2. Strong administrative support contributes to survival of vision as funding decisions are made.
3. One person championing the cause helps a network to succeed, but the champion need not be a manager or in position of authority. Important functions include lobbying for support, fundraising, and identifying resources.
4. Decision makers support the vision.
5. Decision making is shared between district and schools. Some decisions are best made centrally at district level to ensure compatibility among schools. However, schools are best able to determine their individual needs.
6. Districts maintain consistency and integrity of vision and plan. Funding or other opportunities are pursued only if they help the district accomplish their overall educational goals and objectives.

Planning

1. Plan integrates computer networking with district's overall strategic plan and with individual school plans. The computer networking plan links a set of achievable, long-term and short-term goals to the vision. It also provides the basis for proposals for funding.

2. Plan provides all schools with a step-by-step guide book documenting how to implement a computer network at the site level and how to gracefully expand and upgrade the network.
3. The plan is multifaceted and includes the following considerations:
    - Addresses educational goals and integration with curriculum
    - Addresses technical support for users, including training on software and hardware
    - Addresses professional development, with incentives to participate
    - Addresses access for students
    - Provides time for teachers to plan instructional use, train on networking, and explore network capabilities
    - Is informed by needs assessment
    - Provides for a sustainable network, with adequate budget; staffing; and provisions for the development, maintenance, and trouble-shooting of technical infrastructure
    - Addresses selection of infrastructure components based on reliability and performance of network, in addition to cost considerations
    - Identifies strategies to communicate the plan
    - Defines roles and responsibilities of staff and students
    - Involves stakeholders, including parents and community members, in planning process, so they will understand the impact of computer networks, help define the use of networks for their district, and agree upon networking goals and objectives
    - Involves computer network experts and technology coordinators from schools and district in planning process
    - Establishes integration of network with curriculum
    - Links use of computer networking to district-defined goals for student achievement
    - Addresses articulation across grades and across disciplines
    - Provides benchmark through evaluation plan for measuring progress and effectiveness of network implementation in relation to student learning

Operational Policies and Implementation

1. Acceptable use policies govern activities of students and staff on the network.
2. Teachers receive written procedures related to such network issues as use, misuse, technical support, etc.
3. The district provides network access to teachers, students, other school staff, parents, and community members.
4. The district provides network access to students during nonclass hours (lunch, free period, before and after school, etc.).
5. Students are encouraged to use the network outside of school for noneducational purposes.

Teaching and Learning Characteristics and Practices

Administrative Uses

1. Teachers use network capabilities for timely, efficient, and improved communication among students, teachers, parents, administration, and others and to overcome isolation.
2. Teachers use network for submitting grades, recording attendance, sending correspondence, etc., to increase efficiency of operations.
3. Teachers use network capabilities to assess student performance, for example, by creating on-line student portfolios.

Instructional Uses

1. Teachers use network capability to obtain curricula and lessons, to collaborate, to exchange materials, and to share ideas.
2. Teachers use network capabilities to engage students more directly in all aspects of their learning, for example, creating databases, collaborating, making presentations, and accessing a wide variety of resources.
3. Teachers use network capabilities to involve students in tasks and projects that are meaningful and relevant to the students' life and world.
4. Teachers use a wide variety of network capabilities and resources to build classroom activities to complement instruction and to address the diversity of interests and learning styles of their students. In such an environment, students help set their own path through the learning process.
5. Through presentations, multimedia, World Wide Web pages, etc., students reach audiences beyond the school boundaries for feedback from the community, business, parents, etc.

6. Students use networks to collaborate on projects.
7. Students use network-based projects to enhance problem-solving skills.
8. Students use networks to explore careers, training, and job opportunities.
9. Students use networks to develop specific job skills.

Professional Development

1. The district maintains an ongoing plan for staff development.
2. The district provides professional development to all staff, including teachers, aides, substitutes, and administrators.
3. Professional development is tailored to individual needs of teachers and staff.
4. District training complements site-based training.
5. Teachers take hands-on courses on how to integrate network resources into the curriculum and instruction.
6. Teachers take hands-on courses on how to use the network infrastructure, network skills, and tools, e.g., Internet, Web browser, file transfer, etc.
7. Training can be applied by staff immediately upon returning to their sites.
8. Activities are sensitive to the nonuser perspective.
9. Incentives are provided for participating in training.
10. Network capabilities are used to expand teachers' content knowledge.
11. Sources of training include building-level technology coordinators, colleagues, colleges/universities, students, self-instruction, consultants, conferences/workshops, on-line courses, parents, and community members.
12. Programs encourage staff to obtain personal computers at home.
    - The district allows loans of personal computers for staff development at home.
    - The district arranges low-cost financing and educational pricing.

Conclusions and Recommendations

Conclusions

In the Model Nets study we set out to study and characterize the effective use of computer networks by schools. We were especially interested in how districts enlisted computer networks to improve teaching and learning. Overall, our findings confirmed our high expectations for this group of districts, which we had selected for their pervasive use of networks. Driven by the national imperative to "wire" all schools to the information superhighway, these districts had impressive technical infrastructures that supported a wide variety of services. The rapid pace of technological change creates a challenge for school districts in planning and implementing networks, much as it challenged the design of our study. For example, the dramatic emergence of the World Wide Web offers new educational opportunities that barely existed when we began planning the study. Nonetheless, we found that these districts were exploiting these new resources. Almost all have direct access to the Internet. In many cases, these districts have enhanced and expanded the national infrastructure by providing Internet access to their communities, for example, and by creating home pages on the World Wide Web. Districts also have used networking to bring community members and other "outsiders" into the schools electronically and into the wider world of computer networking beyond the schools. Thus their local infrastructures have extended the reach of the national information infrastructure into communities.

As full-fledged participants in the so-called information revolution, districts are struggling with the same issues as business and industry. They are sorting through decisions about hardware and software platforms; about vision, planning, and policy; about learning how to access, sort, edit, and use information from networks; and about appropriate, productive, and *effective* use of the technology. We found that districts use networks to increase administrative efficiency and to make district operations flow more smoothly through distribution of administrative data. For many districts, this administrative efficiency is a

central tenet of their vision of network use. In the domain of teaching and learning, many districts are actively using computer networks in their classrooms. We found that students, teachers, administrators, and other school staff are accessing information, using e-mail, publishing World Wide Web home pages, and otherwise communicating with colleagues, students, their communities, and others beyond their school. This network-facilitated communication is local, national, and international. Networks also give community members, parents, business people, and others a new and convenient means of playing a role in the schools. As a communication medium, networks seemed to have opened up new relationships and invigorated old ones. The heavy reliance on e-mail by school staff in our study confirmed the often-voiced need for better communication by school staff among colleagues and with parents.

Networks appear to spark motivation among teachers and students. Teachers report increased interest in learning among students. We found that network-based on-line information searches and e-mail based communication saved time and made it easy for teachers and students to reach beyond the school building for resources, ideas, information, and camaraderie. As a learning tool, networks appear to be a vast electronic library and e-mail system that provides access to information and to people not otherwise available. Especially for students and teachers in rural, isolated, or impoverished areas, this may be an invaluable benefit. We also found that students are developing workforce readiness skills by performing varied tasks related to storing, retrieving, and manipulating information on networks. Yet we also found that teachers felt networks had less impact on students in higher grades, especially high school students compared to elementary students. But in general, through the site visits and teacher surveys, we found network practices that followed a student-centered, discovery-based model of learning. These are the practices upon which we based the Guidelines for Implementing Effective Computer Networks. However, despite the frequently lofty claims about the impact of networking on students and the obvious evangelizing of many of our interview subjects, we did not find practices for evaluating the impact of computer networks on student learning or achievement. Few of the districts that we studied had plans to evaluate their networks at all. Apparently, few funding agencies or state education agencies required evaluations. We also found very little evidence of professional development for teachers in how to plan curriculum that incorporates student use of computer networks as an integral part of student learning, though many teachers expressed the need for this kind of training.

It is appropriate here to remember a few findings of the study. First, although schools consistently expressed concern about the lack of long-term, stable funding and policy for networks, none of our research suggests inadequacy in the national information infrastructure or in the technology available to (or affordable by) schools to support teaching and learning. Second, many of the districts originally installed their networks to meet perceived administrative needs, then expanded them or created separate networks to support teaching and learning. Finally, only one in five districts assessed their needs before planning and implementing a computer network, which suggests that the districts deemed the networks *a priori* as necessary or a “good thing” for educational applications. However, because local needs were not studied and explicitly identified and because districts have not evaluated the

instructional effectiveness of their networks, we conclude that the common network activities do not *necessarily* meet the specific needs of students in a particular district.

Our research leads us to believe that in the area of networking, most districts have yet to forge the imaginative links among student needs, instructional use, and technological capabilities. Therefore, schools use networks for teaching and learning in the most obvious or pedestrian ways, with scant attention paid to their effectiveness. But districts face a daunting task. In light of their own educational goals and assessments of student need, they must both master the technical issues of implementing a network and grasp the pedagogical opportunities unleashed by the technology. Creative imagination is often intimately linked to one's skills with the tools at hand. To imagine and then implement the *most* effective use of computer networking, districts may find they need to engage in a recursive process of learning about the technology, planning, implementing, learning more, planning again, and so on. Like everyone else, they may find it hard to identify the gaps in their knowledge about networking until they learn more about it, then try something new, then evaluate their results. The rapid pace of technological change only exacerbates the problem. It may take a district a few years of this learning process before they begin to develop innovative applications of networking to meet the particular needs of their students.

In general we did not find that educational goals shaped the planning and implementation of networks. And given that one-fifth of the teachers in our survey had *never used* a network, the technology clearly is not yet integral to their teaching. Only when particular educational goals require the instructional deployment of a computer network can it be considered integral to teaching and learning. Then, in the domain of teaching and learning, the network will become a vital tool in helping the district reach its educational goals.

Our findings in the area of technical infrastructure underscore the need for professional development. Given that we sought districts that were already using networks, we were surprised by the wide variance in and use of their infrastructures. Some districts were just getting started. Others had been using their networks for a few years but had weak systems, such as LANs that were not connected to district WANs or vice versa. We also found districts with less than 56 Kbps bandwidth, which limited the range of services they could exploit on their networks. Yet in most cases, districts appeared to be constrained not by hardware or software, but by their teachers' knowledge of how to get the most out of them. The pedagogical uses of the networks did not reflect the sophistication of the infrastructure. Classroom applications of networks were much the same across all districts, whether they had a state-of-the-art network with full-motion, real-time video transmission capability, or borderline obsolete network without even Microsoft Windows capability. Again, on-line information retrieval and communication were the dominant uses by both teachers and students, activities that can be accomplished at least marginally with low bandwidth. In the study, we found little professional development to educate school staff in the skills necessary for integrating the technology with curricular goals and objectives or classroom activities. Some teachers even pointed out this failing. Thus some of the more technologically sophisticated infrastructures far exceed the current ability of teachers to exploit them. As a

learning tool, computer networks are only as good as the understanding of how to enlist them for *learning* purposes.

In this context, where infrastructure often exceeds the ability of districts to use it, network "scale-up" may best be accomplished by first getting all teachers on-line and by increasing their skills. Investing in their training—both in hardware and software use and in how to use the network to improve their teaching—will allow them to fully exploit network resources and capabilities and to "work smarter" with what they already have. Such professional development can also support the planning process by exposing school staff to the new horizons offered by the technology.

Thus, we are left with a few critical questions that demand further research: Do computer networks improve student achievement? If so, how do they improve it? Do computer networks foster improvements in teaching? Again, if so, how do they foster these improvements? Answering these questions will help schools decide how to best use their limited resources to make the most of computer networks. Given the levels of funding and human energy currently pouring into the implementation of computer networks in schools, these questions warrant conclusive responses based on sound research.

Recommendations

Based on what we have learned from the Model Nets study, we have developed recommendations for additional research and for state and federal agencies that support computer networking in schools. The recommendations are listed below by category.

Recommendations for Further Research

Additional research is required to deepen the understanding of networking in schools, by

- investigating the effect of networking on student achievement and
- conducting a longitudinal study of computer networks in schools by revisiting in 3-5 years a sample of the districts studied under Model Nets.

Recommendations to Funding and Policy-Making Agencies

Federal and state funding agencies should support school-district computer networking projects by providing long-term, stable funding for the following:

- Computer network projects that support local, district, and state education goals
- School district networks that are widely accessible and used by students, teachers, parents, school staff, and community members at large
- Professional development for district and school staff
- Participation of technical experts to plan, design, implement, and maintain computer networks
- Implementation of districtwide WANs and school LANs with voice, video, and data communications capability
- High school networking projects or those districts that provide articulation of networking throughout grades K–12

Appendix A:
List of Participating Sites

Appalachia Educational Laboratory (AEL)

Brunswick County Schools, Lawrenceville, VA

- Totaro Elementary
- Russell Junior High
- Brunswick High

Daviess County Public Schools, Owensboro, KY

- Highland Elementary
- Daviess County Middle
- Apollo High

Fairfax County Schools, Alexandria, VA

- Flint Hill Elementary
- Rocky Run Middle
- Herndon High

WestEd (formerly Far West Laboratory for Educational Research and Development)

Mendocino Unified School District, Mendocino, CA

- Mendocino Grammar
- Mendocino Middle
- Mendocino High

Monterey Peninsula Unified School District, Monterey, CA

- George C. Marshall Elementary
- Martin Luther King Middle
- Seaside High

Oakland Unified School District, Oakland, CA

- Manzanita Elementary
- King Estates Middle
- Fremont High

Mid-continent Regional Educational Laboratory (McREL)

Boone County R-IV Schools, Hallsville, MO

Boulder Valley District R-2, Boulder, CO

- Nederland Elementary
- Platt Middle
- New Vista High

Poudre Valley District R-1, Fort Collins, CO

- Tavelli Elementary
- Preston Junior High
- Rocky Mountain High

Sweetwater County School District #2, Green River, WY

- Truman Elementary
- Monroe Middle
- Green River High

North Central Regional Educational Laboratory (NCREL)

Indianapolis Public Schools, Indianapolis, IN

- Washington Irving Elementary (IPS #14)
- Harshman Middle (IPS #101)
- Arsenal Technical High

Mankato Public Schools Independent School District 77, Mankato, MN

- Kennedy Elementary
- Dakota Meadows Middle
- Mankato East High

Northville Public Schools, Northville, MI

- Thornton Creek Elementary
- Meads Mill Middle
- Northville High

Urbana Schools #116, Urbana, IL

- Leal Elementary
- Urbana Middle
- Urbana High

Verona Area School District, Verona, WI

- Country View Elementary
- Verona Area Middle
- Verona Area High

Regional Laboratory for the Educational Improvement of the Northeast and Islands, Inc. (NEIRL)

Lexington Public Schools, Lexington, MA

- Fiske Elementary
- Maria Hastings Elementary
- Diamond Middle
- Lexington High

SCT BOCES (Schuyler, Chemung, Tioga Board of Cooperative Educational Services), Elmira, NY

- Cohen Elementary, Elmira Heights
- Broadway Elementary, Elmira City
- Horseheads High, Horseheads
- Edison High, Elmira Heights

Northwest Regional Educational Laboratory (NWREL)

Bellevue School District, Bellevue, WA

- Phantom Lake Elementary
- Highland Middle
- Sammamish High

Eugene School District 4J, Eugene, OR

- Willagillespie Elementary
- Roosevelt Middle
- South Eugene High

North Slope Borough School District, Barrow, AK

- Ipalook Elementary - Barrow
- Hopson Middle - Barrow
- Barrow High - Barrow
- Nunamiut (K-12) - Anaktuvuk Pass

Saco Public Schools, Saco, MT

Pacific Regional Educational Laboratory (PREL)

Island of Kaui

- Wilcox Elementary, Lihue, HI

Island of Oahu

- Koko Head Elementary, Honolulu, HI
- Waialua Elementary, Waialua, HI
- Kailua Intermediate, Kailua, HI

Island of Maui

- Maui High, Kahului, HI

Research for Better Schools (RBS)

Maryland Virtual High, Montgomery County, Silver Spring, MD

Montgomery County Intermediate Unit, Norristown, PA

- Merion Elementary, Lower Merion School District
- Colonial Middle, Colonial School District
- Upper Perkiomen High, Upper Perkiomen School District

Princeton Regional Schools, Princeton, NJ

- Johnson Park Elementary
- John Witherspoon Middle
- Princeton High

Southwest Educational Development Laboratory (SEDL)

Dell City Independent School District, Dell City, TX

Monroe City Schools, Monroe, LA

- Lincoln Elementary
- Sally Humble Elementary
- Jefferson Junior High
- Wossman High

Pocahontas Independent School District, Pocahontas, AR

- Alma Spikes Elementary
- M.D. Williams Intermediate
- Pocahontas High

SouthEastern Regional Vision for Education, Inc. (SERVE)

Carrollton City Schools, Carrollton, GA

- Carrollton Elementary
- Carrollton Middle
- Carrollton High

Escambia County Schools, Pensacola, FL

- L.D. McArthur Elementary
- Brown Barge Middle
- Pine Forest High

Moss Point School District, Moss Point, MS

- Kreole Elementary
- West Elementary
- Magnolia Junior High
- Moss Point High

Winston Salem/Forsyth School District, Winton-Salem, NC

- Moore Alternative Elementary
- Cook Middle
- Mt. Tabor High

Appendix B: Regional Educational Laboratory Liaisons and Site Visit Teams

Regional Educational Laboratory Liaisons

Carolyn Carter
Appalachia Educational Laboratory (AEL)
Charleston, WV

John Cradler
WestEd (Far West Laboratory for Educational Research and Development, FWL)
San Francisco, CA

Linda Brannan
Mid-Continent Regional Educational Laboratory (McREL)
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Ray Ramirez
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Portland, OR

Paul Dumas
Pacific Regional Educational Laboratory (PREL)
Honolulu, HI

Patsy Wang-Iverson
Research for Better Schools (RBS)
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Austin, TX

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SouthEastern Regional Vision for Education (SERVE)
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Phase II Site Visit Teams

AEL Team

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Hilary Cowen
South Charleston, WV

WestEd Team

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REA and Associates
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Far West Laboratory Educational Research and Development
San Francisco, CA

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McREL Team

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NCREL Team

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Oak Brook, IL

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NEIRL Team

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Washington, D.C.

SEDL Team

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Rio Rancho, NM

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Cathey, Hutton and Associates
Austin, TX

David Rainey
Principal, Arkansas School for Math and Science
Hot Springs, AR

SERVE, Inc. Team

Nancy Verber
SouthEastern Regional Vision for Education
Atlanta, GA

Rick Clifton
Program for Rural Services and Research
University of Alabama
Cedar Bluff, AL

Appendix C: Research Questions

Technical Infrastructure

1. Describe the wide area network. Include descriptions of the topology, bandwidth, connectivity, type of netware, and the number, type, and location of workstations. (WAN)
2. Describe the functions of the network, including uses for administration, professional development, and teaching and learning. Describe the type of software accessible on the network and the uses of the software. (USES)
3. Describe the external networks to which the wide area network connects and the uses of these connections. (EXTERNAL)
4. Describe how the network is managed and maintained. Include profiles(s) of the network manager(s), cost of management, and the mechanisms for upgrades to the network. (MANAGEMENT)
5. Describe how technical support is provided on the network. (SUPPORT)
6. Describe how security of the network is maintained and how issues concerning security are resolved. (SECURITY)
7. Describe the network performance, flexibility, and reliability. (PERFORMANCE)
8. Describe who has access to the network, how often they have access, and the general traffic patterns on the network. (ACCESS)
9. Describe any obstacles or barriers to enhancing the network infrastructure. (BARRIERS)

10. Describe any unique opportunities that have facilitated or enhanced the development or use of network technology. (CATALYSTS)
11. Describe the network's evolution and plans for the future evolution of the network. (PAST/FUTURE)

Policy

1. Describe the vision concerning the use of the network. (VISION)
2. Describe the local, state, or federal policies that impact the network. Include a discussion of policies dealing with appropriate use of the network. (POLICIES)
3. Describe any network planning process, including representatives involved in planning. (PLANNING)
4. Describe how resources are allotted for network use and maintenance, include a summary of budgeting and staffing concerns, allocations of space and equipment, and provisions for growth and updating of equipment. (RESOURCES)
5. Describe how funding for the network is determined. Include the percentages of funds allocated for network use, where the funds come from, and how decisions are made about priorities and purchases. (FUNDING)
6. Describe the role the community members (e.g., parents, businesses, higher education, etc.) play in planning, implementing, using, and evaluating the network. (COMMUNITY)
7. Describe the plans or processes for measuring costs and benefits of networking technology within the district. (EVALUATION)
8. Describe how the district elicits support for networking technology efforts and the role of leadership in promoting the vision. (LEADERSHIP)
9. Describe who has access to the network, policies related to access and equity, and the general traffic patterns on the network. (ACCESS)
10. Describe any obstacles or barriers related to policy issues that impact network uses. (BARRIERS)
11. Describe any unique opportunities that facilitated or enhanced the development or use of network technology. (CATALYSTS)
12. Describe how policies related to the network have evolved and plans for future policies regarding network use. (PAST/FUTURE)

Teaching and Learning

1. Describe the uses of the network by teachers, including uses for professional development, administrative functions, instruction, and assessment. (TEACHER USE)
2. Describe the uses of the network by students, including curricular and extracurricular. (STUDENT USE)
3. Describe how the impacts of the networking technology on teacher and student performance are assessed. (ASSESSMENT METHODS)
4. Describe any impacts that the network has had on teaching and learning, including changes both positive and negative in school organization, decision-making process, curricular content, instructional delivery, teacher preparation, and student performance. (IMPACTS)
5. Describe the process of formal training on the network, including how often it occurs, who does the training, and how effective training is. (TRAINING)
6. Describe any informal learning and/or support process related to network uses, including support groups, on-line connections, or other means to learn about new uses of the network. (SUPPORT)
7. Describe the physical environments where educators and students access networking technology. Describe the influence of the environment on the frequency and ease of access for both teachers and students. (ENVIRONMENT)
8. Describe student and teacher access to the network, how often they have access, and the general traffic patterns on the network. (ACCESS)
9. Describe any obstacles or barriers encountered in using the network for teaching/learning purposes. (BARRIERS)
10. Describe any unique opportunities that facilitated or enhanced the development or use of network technology. (CATALYSTS)
11. Describe how teaching/learning uses of the network have evolved and future plans for uses of the network. (PAST/FUTURE)

Appendix D: Instruments

The following instruments are included here:

- Superintendent Interview Questions
- District Technology Coordinator Interview Questions
- Principal Interview Questions
- Building Technology Coordinator Interview Questions
- Teacher Focus Group Questions
- Student Focus Group Questions
- Classroom or Lab Observation Protocol
- National Survey of Teachers

MODEL NETS
SUPERINTENDENT INTERVIEW

District: _____
Date and Time of Interview: _____
Name of Interviewee: _____
Duration and Location of Interview: _____
Interview Conducted By: _____

1. What do you want to accomplish with networking technology in your district? What are your goals?
   a. How is this vision shared with others?
   b. How do you elicit support for networking?
      1. From potential funders?
      2. From potential users within the district?
      3. From the community?

2. What planning process has facilitated the development of network technology in your district?
   a. Who was/has been involved?
   b. When did this process start? How long has it taken? Is it still continuing?

3. What provisions are there to ensure growth and update of the network?

4. How do you evaluate the impact and effectiveness of the network? What impact has network technology had on the district? *(Ask about teaching/learning, district business, administrative functions, policies, decision-making, attitudes, etc.)*

5. How do you assess the cost and benefits of networking technology in the district?
   a. Assessment process:
   b. Parties involved:

6. How is funding determined for the network? Who is involved in the decision-making process?
   a. How are decisions made about priorities and purchases?
   b. Who is involved in the decision-making process?
   c. What percent of the district budget goes for network use?
   d. What are the sources of funding for networking?
      - state grants
      - federal grants
      - PTO
      - corporate grants
      - district budget
      - special initiative
      - other
   e. What is the total estimated cost?

7. What resources have you allocated for ongoing network maintenance?
   a. How are resources allocated for ongoing network maintenance?
   b. Who makes the decisions?
   c. What are your major budget and staffing concerns?
   d. What does the district provide and what is the school responsible for?
   e. What budget provisions, if any, has the district made for growth of the network and for updating the equipment?

8. What federal, state, or local policies affect networking in this district? *For example: policies on appropriate/ethical use of networking, security, provisions for evaluation, equal access, etc.*
   a. Federal policies:
   b. State policies:
   c. District policies:

9. Describe any district or school site policies regarding use, users, frequency of use and/or access to the network.

10. Describe the role played by the local community related to networking technologies.

11. Describe how policies related to the network have evolved.

12. Do you foresee needs for any future policies regarding network issues? Explain.

13. What barriers or obstacles related to networking technologies have you faced? Describe the barriers or obstacles and how you have dealt with them.

14. Describe any unexpected or unique opportunities that have contributed to or facilitated the use of network technologies.

15. Is there anything else you would like to add about network technologies in the district?

Thank you very much for your cooperation with our study.

MODEL NETS
DISTRICT TECHNOLOGY COORDINATOR INTERVIEW

District: _____
Date and Time of Interview: _____
Name and Title of Interviewee: _____
Duration and Location of Interview: _____
Interview Conducted By: _____

1. Describe your network. (LAN, WAN). *Ask for schematic of the network if one is available. If not, ask the coordinator to draw one for you.*
   a. Describe the WAN. *Include descriptions of topology, bandwidth, connectivity, type of netware, number, vendor, and location of stations.*
   b. Describe external networks connected to WAN.
   c. Describe the services that are available on your network (voice, video, data).

2. Describe the functions of the network.
   a. For administration:
   b. For professional development:
   c. For teaching and learning:
   d. For training:
   e. Other:

3. Describe who has access to the network, where, when, how often, and the patterns of traffic.
   a. Who:
   b. Where:
   c. When:
   d. How often:
   e. Traffic patterns:
   f. Access limitations:
      - What, if anything, limits access to the network?
      - Does the physical environment influence the use of networking? Explain.

4. Describe how the network is managed and maintained.
   a. Profile of network manager(s):
   b. Cost of management:
   c. Mechanisms for upgrades:

5. Describe the training available to network users.
   a. Training method/process:
   b. Frequency:
   c. Effectiveness:
   d. Informal assistance/support for network users:

6. Describe how technical support is provided on the network.
   a. Who provides the support?

   b. For whom is the support provided?
   c. What is the process/mechanism used to provide support?
   d. How is the support perceived?

7. Describe how the security of the network is maintained.
   a. Process/mechanism:
   b. How are security issues resolved?

8. Describe the network performance, reliability, and flexibility.

9. Explain how funding for the network is determined and how resources are allotted.
   a. Who is involved in the decisions?
   b. How are decisions made regarding priorities and purchases?
   c. How are resources allocated for network use?
   d. How are resources allocated for network maintenance?
   e. What budget provisions are being made for growth of the network and update of equipment?

10. Describe the process used to measure cost/benefits of networking technology in the district.

11. Describe the impact networking has had on your district. How is the impact assessed?
   a. District business:
   b. District organization:
   c. Student performance:
   d. Student attitude:
   e. Teaching practices (curriculum, instruction, assessment, etc.):
   g. Teacher performance (knowledge/skills, attitudes, etc.):
   h. Achievement of district goals:

12. Describe network planning processes and who was/is involved.
   a. Process:
   b. Participants:
   c. Community involvement:

13. What barriers or obstacles have you faced in making the vision for networking a reality in the district? Describe how you have dealt with the barriers or obstacles.

14. Describe any unexpected or unique opportunities that have contributed to or facilitated the use of network technologies.

15. What plans have been made to upgrade and expand the network system in the future?

16. Is there anything else you would like to tell us about networking in your district?

Thank you very much for your cooperation.

MODEL NETS
PRINCIPAL INTERVIEW

District: _____
Date and Time of Interview: _____
Name of Interviewee: _____
Duration and Location of Interview: _____
Interview Conducted By: _____

1. What do you want to accomplish with networking technology in your school?
   a. What are your goals?
      1. Administrative goals:
      2. Professional development goals:
      3. Teaching and learning goals:
      4. Other goals:
   b. How do you elicit support for networking?
      1. Community:
      2. Staff:
      3. Others:

2. How do you share your vision with others?

3. How is networking technology currently being used in the school?
   a. Administrative uses:
      1. Administrators:
      2. Office staff:
      3. Teachers:
      4. Other staff:
   b. Professional development:
   c. Teaching and learning:
   d. Other:

4. Where are the gaps between the district/school goals for network technology and current practice? What are the plans to close those gaps?

5. What type of training on the network has been/is being provided?
   a. Who does/has done the training?
   b. Who is it intended for?
   c. Who participates/has participated?
   d. How effective is it/has it been?
   e. What type of support, if any, is provided or available to network users?

6. Are there any district or site policies regarding access to the network? Describe them.
   a. Use/access:
   b. Users:
   c. Frequency of use:
   d. Prerequisites for use:
7. Describe the impact networking has had at your school. Describe how the impact is assessed.
8. How is the community involved in networking technology at the school? Describe.
9. Describe how funding is determined for network technology (hardware and software).
   a. Who is involved in funding decisions?
   b. How are decisions made about priorities and purchases?
10. Describe how resources are allotted for network use and maintenance (space, facilities, workstations, personnel).
    a. Who makes these decisions?
    b. What budget provisions have been made, if any, for growth and update of equipment?
    c. What plans are there for changing/upgrading the network system in the future?
11. What barriers and/or obstacles have you faced in making the vision for network technology a reality in your school (e.g., support, technological problems, resistance, logistics, facilities, etc.)? How have you dealt with these barriers or obstacles?
12. Describe any unexpected or unique opportunities that have contributed or facilitated the use of network technologies.
13. Is there anything else you would like to tell us about network technology in your school or district?

Thank you very much for your cooperation.

MODEL NETS
BUILDING TECHNOLOGY COORDINATOR INTERVIEW

District: _____
Date and Time of Interview: _____
Name of Interviewee: _____
Duration and Location of Interview: _____
Interview Conducted By: _____

1. Describe your network. (LAN, WAN). Ask for schematic of the network if one is available. If not, ask the coordinator to draw one for you.
   a. Describe the WAN. Include descriptions of topology, bandwidth, connectivity, type of netware, number, vendor, and location of stations.
   b. Describe external networks connected to WAN.
   c. Describe the services that are available on your network (voice, video, data).

2. Describe the functions of the network.
   a. For administration:
   b. For professional development:
   c. For teaching and learning:
   d. For training:
   e. Other:

3. Describe who has access to the network, where, when, how often, and the patterns of traffic.
   a. Who:
   b. Where:
   c. When:
   d. How often:
   e. Traffic patterns:
   f. Access limitations:
      - What, if anything, limits access to the network?
      - Does the physical environment influence the use of networking? Explain.

4. Describe how the network is managed and maintained.
   a. Profile of network manager(s):
   b. Cost of management:
   c. Mechanisms for upgrades:

5. Describe the training available to network users.
   a. Training method/process:
   b. Frequency:
   c. Effectiveness:
   d. Informal assistance/support for network users:

6. Describe how technical support is provided on the network.
   a. Who provides the support?
   b. For whom is the support provided?
   c. What is the process/mechanism used to provide support?
   d. How is the support perceived?

7. Describe how the security of the network is maintained.
   a. Process/mechanism:
   b. How are security issues resolved?

8. Describe the network performance, reliability, and flexibility.

9. Explain how funding for the network is determined and how resources are allotted.
   a. Who is involved in the decisions?
   b. How are decisions made regarding priorities and purchases?
   c. How are resources allocated for network use?
   d. How are resources allocated for network maintenance?
   e. What budget provisions are being made for growth of the network and update of equipment?

10. Describe the process used to measure cost/benefits of networking technology in the school.

11. Describe the impact networking has had on your school. Describe how the impact is assessed.

12. Describe network planning processes and who was/is involved.
    a. Process:
    b. Participants:
    c. Community involvement:

13. What barriers or obstacles have you faced in making the vision for networking a reality in the school? How have you dealt with these barriers or obstacles?

14. Describe any unexpected or unique opportunities that have contributed to or facilitated the use of network technologies.

15. What plans have been made to upgrade and expand the network system in the future?

16. Is there anything else you would like to tell us about networking in your school?

Thank you very much for your cooperation.

MODEL NETS
TEACHER FOCUS GROUP

Conducting the Focus Group

Welcome: *After all participants and research team members are seated, the Moderator should thank the teachers for participating and then introduce the research team members. The Moderator should next explain (a) the purpose of the study; (b) why the participants were selected for this focus group; (c) the general nature of the questions which will be asked; (d) how the data will be used; and (e) the time frame for the focus group.*

> **Sample Explanation:** The Department of Energy, in collaboration with the Department of Education's Regional Education Labs, has initiated a national study to explore models for K–12 education in the National Information Infrastructure. Your district and your school have been identified as innovators in the use of networking and telecommunications technologies in the (*identify region*). You have been selected for this focus group because of your own unique experiences with the use of these technologies. Today we want to talk with you about your experiences with using these technologies. The information that we collect will be used to guide both federal agencies and school districts in planning, implementing, and evaluating K–12 network models. We will be on a first name basis today but in our later reports no names will be attached to comments. You may be assured of complete confidentiality. As we begin talking please feel free to voice any ideas you have but let's have only one person talk at a time. This session should last approximately 45 minutes to 1 hour.

For the first question, the Moderator should proceed round robin around the group, letting each participant respond.

Opening Question: Could you please tell us your name and what you teach?

You may find it helpful to draw a sketch identifying where teachers are sitting.

Sketch:

Focus Group Research Questions

1. Describe how you use the network.
   a. Administrative purposes:
   b. Instructional purposes:
   c. Professional development:
   d. Assessment:
   e. Communication:
   f. Other:

2. Describe how your students use the network.
   a. Uses (curricular/extracurricular):
   b. Patterns of use:
      - Grouping patterns (e.g., single users, cliques, clubs)
      - Gender use patterns

3. Describe what impact networking has had in your school and in your classroom. Describe how the impact is assessed.

4. Describe who has access to the network and the patterns of traffic (students, educators, others). *Probe for details.*
   a. Levels of access (degree of connectivity)
   b. Prerequisites required for use (training, signed contract, etc.)
   c. Average time on the network
   d. Frequency of use

5. What type of training on the network has been or is being provided?
   a. Who has done the training?
   b. Who is the training intended for?
   c. Who has participated in the training?
   d. How effective has the training been?

6. Describe any informal assistance, learning, or support processes for network users.
7. Describe the physical environments where educators and students access networking technology. Describe the influence of the physical environment on the following.
   a. Types of use
   b. Frequency of use
   c. Ease of use
8. Describe the network planning process at your school and who has been involved.
   a. Process
   b. Participants
   c. Community involvement
9. How are decisions made regarding hardware and software purchases, staff development, or other network-related needs?
   a. Hardware/software decisions
   b. Staff development decisions
   c. Other
10. What barriers and/or obstacles have you encountered in using the network for teaching and learning purposes? (e.g., support, technological problems, resistance, logistics, facilities, etc.). How have you dealt with the barriers or obstacles?
11. Describe any unexpected or unique opportunities that have contributed to or facilitated the use of network technology in your classroom or in your school?
12. Describe how the uses of the network have evolved and what the plans are for future uses of the network.
13. Is there anything else you would like to tell us about network technology in your classroom or school?

Closing: Thank you very much for your participation today. If you think of other comments to add to this discussion, please feel free to contact one of us. The results of this research will be sent to the school later this year, and your district will have an opportunity to comment on the findings.

MODEL NETS
STUDENT FOCUS GROUP

Conducting the Focus Group

Welcome: *After all participants and research team members are seated, the Moderator should thank the students for participating and then introduce the research team members. The Moderator should next explain (a) the purpose of the study; (b) why the participants were selected for this focus group; (c) the general nature of the questions which will be asked; and (d) the time frame for the focus group.*

> **Sample Explanation:** The Department of Energy, in collaboration with the Department of Education, is conducting a national study to explore models for K–12 schools in the National Information Infrastructure—the so-called Information Superhighway. Your district and your school have been identified as innovators in the use of networking and telecommunications technologies in the (*identify region*). You have been selected for this focus group because of your own unique experiences with the these technologies. Today we want to talk with you about your experiences with using telecommunications and networking. As we begin talking please feel free to voice any ideas you have but let's have only one person talk at a time.

For the first question, the Moderator should proceed round robin around the group, letting each participant respond.

Opening Question: Could you please tell us your name and what grade you are in?
You may find it helpful to draw a sketch identifying where students are sitting.

Sketch:

Student Focus Group Research Questions

1. How do you and other students use the network in your school? *Probe for details.*
   a. Curricular activities (school projects, communicating with teachers, etc.)
   b. Extracurricular activities (MUDs or similar activities, games, etc.)

2. Who uses the network and how often?
   a. Do certain groups, students, or classes use the network more than others? Explain.
   b. What requirements/prerequisites are there for using the network?

3. What rules or guidelines are students required to follow regarding appropriate use of the network?
   a. How are the rules enforced?
   b. What are you able to do on the network? What aren't you able to do?
   c. How is access obtained?

4. How does the location of the computers influence your use of the network? Explain.

5. What kind of training do students receive before using the network?

6. What type of support or help is available for network activities or problems?

7. Has the presence of the network changed anything in the classrooms or school?
   a. Have lessons, assignments, homework, communication, or tests changed as a result of network technology? How? Explain.
   b. How do you feel about using the network? Why?

8. How has using the network impacted
   a. what you are learning?
   b. how you are doing in school?
   c. your attitude about school?
   d. your attitude about learning in general?

9. What kinds of problems have you encountered when using the network? How did you deal with these problems?
10. What do you like best about using the network? What do you like least?
11. What would you like to be able to do with the network in the future that you can't do now?
12. Is there anything else that you'd like to share with us?

Thank you very much for your help.

MODEL NETS
CLASSROOM OR LAB OBSERVATION PROTOCOL

District: _____
Date and Time of Observation: _____
Observer: _____
Teacher/staff observed: _____
Grade Level(s): K 1 2 3 4 5 6 7 8 9 10 11 12
Subject(s) Presented: _____
Location of Observation: 5 classroom
4 teachers' room/lounge
3 student computer lab
2 school office
1 other: _____

Number of Students Present: _____
Networks Available: WAN LAN

Ask the instructor to demonstrate or explain a project that involves student use of networking (preferably a longer project which may last several days or weeks). Ideally, you'd like to be able to observe some small part of the project.

1. Briefly describe project.
   a. What are the major learning objectives?
      Objectives related to networking:
      Other objectives:
   b. What are the major activities?
   c. What are the major student products?

2. How are students using the network? *(circle letter if students use)*
   a. To communicate with other students within district
   b. To communicate with other students outside the district or in other countries
   c. To communicate with teachers
   d. To communicate with experts at universities, businesses, or organizations
   e. To participate in online discussion groups
   f. To use bulletin boards or newsgroups
   g. To conduct a library or literature search
   h. To access databases of information
   i. To transfer files
   j. To gain remote access to another computer
   k. To explore the Internet on their own
   l. Other: _____

3. How is student use of the network important to the achievement of desired student outcomes in project?

4. Describe how the instructor assesses or will assess student learning in this project.

5. Does <u>every</u> student use the network for this project? *(circle one)* Y N

6. How are students grouped to work on the network for this project? *(circle as many as are appropriate)*

   solo pair small group

   w/other classes w/other grades w/students outside this school

7. Does project call for any of the following? *(circle the letter if project calls for)*

   a. Teacher time one-on-one with students
   b. Use of cooperative groups
   c. Focus on critical thinking skills
   d. Attention to skills of locating and accessing information
   e. Emphasis on depth rather than breadth of knowledge
   f. Complex multidisciplinary tasks
   g. Links between class assignments and "real world" outside classroom
   h Links between class assignments and local, state, or national standards
   i. Extensive writing
   j. Extensive reading
   k. Extensive mathematical calculation and analysis
   l. Extensive scientific investigation and analysis
   m. Alternative assessment strategies (e.g., exhibitions, portfolios)

8. If a student has problems trying to use the network, what happens to the student? To others? To the lesson?

9. Overall, how would you characterize students' attitudes towards using the network as part of the project. *(circle one)*

   eager neutral reluctant other: _____

10. Overall, how would you rate the way in which the project/lesson integrated networking? *(circle one)*

    5 Excellent, worthwhile integration
    4 Good
    3 Okay
    2 Weak
    1 Very poor

11. Describe any evidence in the room of student use of networks (e.g., logs of databases accessed, well-used manuals, bulletin boards w/ e-mail pen pal letters, sign-up sheets for computer use, printouts of primary source documents, etc.).

    Comments:

MODEL NETS
NATIONAL SURVEY OF TEACHERS

Sponsored by the U.S. Department of Energy and the U.S. Department of Education Regional Educational Laboratories

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The purpose of this survey: Your school district is one of 30 around the country being studied for its use of computer networking. Please complete the following survey to help us understand how you use the network available through your school and how you perceive that networking has impacted teaching and learning at your school. Your responses will be kept completely confidential. The results of this survey, however, will be used to influence policies about networking in schools throughout the country, so we very much appreciate your cooperation.

Instructions: Please complete this survey by circling the number corresponding with your answer or by recording your comments.

1. Grade level(s) currently teaching: K 1 2 3 4 5 6 7 8 9 10 11 12

2. Subject(s) currently teaching: _____

3. How many years have you been a teacher? _____ years

4. How comfortable do you feel with computers at present?

   5 very comfortable
   4 somewhat comfortable
   3 neutral
   2 somewhat uncomfortable
   1 very uncomfortable

	YES	NO
5. Do you own a personal computer?	1	2
6. Does your classroom have a computer in it?	1	2
6a. If yes, do you have a phone and modem?	1	2
6b. If yes, are you on a network (LAN/WAN)?	1	2
7. Have you ever used a computer network?	1	2
8. Do you have an electronic mail (e-mail) address now?	1	2

Your address is: _____

9. What types of training and support for networking have you used and how effective were they? (Check whether or not training is available and whether you have used it. Indicate how effective it was.)

	Available?	Used?	Not Effective	Effective	Very Effective
	1	2	3	4	5
a. self-taught					
b. friends or colleagues					
c. school technology coordinator or specialist					
d. district technology coordinator or specialist					
e. consultant					
f. vendors					
g. state-sponsored training					
h. regional or national training, (e.g., conferences)					
i. college or university course					
j. online instruction or support					
k. students					
l. parents or community members					
m. other: _____					

10. Here are some ways in which teachers might use networking. How often do you typically use the network in these ways?

5=daily
4=weekly
3=monthly
2=once or twice a year
1=never

a. communicate with colleagues within the district
b. communicate with colleagues outside the district
c. communicate with people at universities, agencies, or organizations
d. communicate with parents
e. check or report on student information (grades, attendance, etc.)
f. participate in online discussion groups
g. use bulletin boards or newsgroups
h conduct a library or literature search
i. access databases for educational purposes
j. transfer files
k. gain remote access to another computer
l explore the Internet
m. other: _____

11. What uses of the network would you like to learn more about?

12. In general, how supportive is your school administration [of networking]?

    5 very supportive
    4 somewhat supportive
    3 neutral
    2 somewhat unsupportive
    1 very unsupportive

13. Where do you usually get on the network? (Check all that apply.)

    6 my home
    5 my classroom
    4 teachers' room
    3 student computer lab
    2 school office
    1 other: _____

14. When do you typically get on the network? (Check all that apply.)

    6 before school
    5 during breaks or lunch
    4 during class
    3 after school
    2 evenings/weekends
    1 summers/holidays

15. On average, how many hours per week do you use a network? _____ hours

16. Does anything make it difficult to use the network as much as you would like? (Check all that apply.)

    7 inconvenient place to access
    6 inconvenient access times
    5 complicated access procedures
      network is unreliable—it tends to break down a lot
    4 not enough training
      network is too slow—it doesn't have enough bandwidth to do what I want
    3 not comfortable with computers
    2 no reason to use the network
    1 other (please explain)

17. What impact has your use of networking had on you personally or professionally?

    5 increased very much
    4 increased somewhat
    3 no effect
    2 decreased somewhat
    1 decreased very much

a. time or effort spent on administrative requirements (e.g., filing grades, etc.)
b. time spent in meetings
c. time spent in professional development
d workload
e my job efficiency
f. communication and sharing ideas or materials with colleagues
g. exchange of ideas or materials with people at universities, agencies, businesses, or other organizations
h. my content knowledge in subject(s) I teach
i. breadth or depth of my interest in subject matter
j. my repertoire of teaching strategies
k. my repertoire of student assessment strategies
l. materials and resources to use with my class
m. my comfort and enthusiasm with technology in general
n. my enthusiasm for teaching in general
o. isolation in teaching
p. overall quality of my teaching

18. Do your students use networking in your classes? 1 yes 2 no If no, skip to question 27.

19. How frequently do students have access to networking in your class?

6 daily
5 few times a week
4 once a week
3 few times a month
2 once a month
1 occasionally during the year

20. In general, how do your students feel about networking?

5 like very much
4 like somewhat
3 neutral
2 dislike somewhat
1 dislike very much

21. How has your teaching been influenced by availability of networking to students?

5 increased very much
4 increased somewhat
3 no effect
2 decreased somewhat
1 decreased very much

a. students work independently
b. teacher time one-on-one with students
c. use of small cooperative groups
d. focus on critical thinking skills

e. attention to skills of locating and accessing information
f. emphasis on depth rather than breadth of knowledge
g. complex or interdisciplinary projects
h. link class assignments to "real world" outside classroom
i. link class assignments to local, state, or national standards
j. amount or types of writing
k. amount or types of reading
l. amount or types of math or science
m. assessments strategies such as investigations, demonstrations, exhibitions, portfolios, teacher observation, or peer review

22. Other important ways teaching or learning has changed in your class?

23. How often do your students typically use the network in the following ways?

5=daily
4=weekly
3=monthly
2=once or twice a year
1=never

a. communicate with other students within district
b. communicate with other students outside the district or in other countries
c. communicate with teachers
d. communicate with people at universities, businesses, or organizations
e. participate in online discussion groups
f. use bulletin boards or newsgroups
g. do a library or literature search
h. access encyclopedias
i. access databases for information
j. transfer files
k. gain remote access to another computer
l. explore the Internet on their own
m. other: _____

24. In the future, how would you like students to use the network differently?

25. Is there anything that makes it difficult to make good use of the network for class?

26. What impact has using a network had on your students in the following areas?

    5 increased very much
    4 increased somewhat
    3 no effect
    2 decreased somewhat
    1 decreased very much

    a. overall level of academic achievement
    b. interest in school
    c. interest in particular subjects or topics
    d. knowledge of one or more particular subject areas
    e. skill in locating and accessing information
    f. amount and quality of sources used in writing papers, doing projects, etc.
    g. time engaged in learning
    h. communication and sharing with other students
    i. communication with teachers or other education professionals
    j. communication with universities, agencies, businesses, or other organizations
    k. comfort [with] and enthusiasm [for] computers in general
    l. ability to work in cooperative teams or groups
    m. self confidence or esteem
    n. respect from peers
    o. other:_____

27. What impact has access to a network had on your school as a whole?

    5 improved very much
    4 improved somewhat
    3 no effect
    2 declined somewhat
    1 declined very much

    a. general staff morale
    b. sense of empowerment to address school issues
    c. ability to work as a team to identify goals, make decisions, solve problems
    d. sharing of ideas and skills with others in the district
    e. efficiency or effectiveness of school management
    f. relationship with parents
    g. relationship with community
    h. overall quality of teaching
    i. overall level of student achievement

28. Does anyone evaluate how useful or effective your use (or your students' use) of the network is?

    [ ] no [ ] unsure [ ] yes

    If yes, who does it?_____
    When?_____

29. How would you feel if your network connection were eliminated?

happy, relieved sad, angry, frustrated

1 2 3 4 5 6 7 8 9 10

Comments:

30. What 3 things would you tell other teachers whose school or district might make networking available to them?

Many thanks for your cooperation!

Appendix E: Network Services

During the Model Nets study, we found districts effectively using various network services, each of which the districts can either access as a "client" or provide as a "server." Below we describe network services that districts find useful or that should be considered when a district plans its technical infrastructure. To effectively access or provide these services, the district must consider a few factors: bandwidth; the demand for service over the network, which is generally proportional to the number of users; and the hardware/software platform that will carry the services. For a service to be viable at a given bandwidth, system response time must be acceptable to the average user. Some services are possible at a given bandwidth, but the performance would be unacceptable. Detailed considerations about the network platform are dependent upon more variables than we can discuss here, including the particular needs of an individual district. We have provided in this appendix a brief synopsis of useful services.

The following services are discussed:

- E-mail
- Network news groups
- Information services
- Name services
- File sharing
- Conferencing
- Printer sharing
- Terminal connections

Assumptions

The following assumptions underpin any analysis of requirements for technical infrastructure and bandwidth:

- Network performance is a function of demand for service and bandwidth. The more data a network transfers, the more bandwidth is required to provide adequate service.
- Serving multiple users requires more bandwidth than serving a single user; the required bandwidth generally increases as the demand on services increases.
- Demand for network services is proportional to the number of network users.
- Transferring multimedia data requires greater bandwidth than transferring simple text data.
- Clients perform one function with one server at a time, while servers (that is, providers) perform many functions simultaneously for multiple clients.

E-mail

E-mail is one of the most widespread services that we found on networks in Model Nets districts. Currently the most effective mail systems allow people to exchange mail—that is, both send and receive—with others that are on the same or different mail systems. Because e-mail is generally simple text, it is useful even over lower bandwidth connections. More sophisticated mail systems allow multimedia data or other files to be attached to the message, thus increasing the minimum bandwidth required for acceptable service. E-mail tends to be most successful when a large community of users relies on it for communication.

The basic service is the e-mail system itself. Effective e-mail systems will allow the exchange of mail with different mail systems using international industry standards. The basic electronic mail protocol for the Internet is the simple mail transfer protocol (SMTP). This allows for the exchange of e-mail between Internet mail servers. One extension to the basic mail service between networks is a post office protocol (POP) server. A POP service allows someone on a personal computer to easily fetch mail from an SMTP mail server. POP service does not require the computer to always be available to receive mail. POP also supports friendlier user interfaces on personal computers for reading mail.

Multipurpose Internet mail extension (MIME) is another extension to the basic Internet mail service. MIME is a standard for multimedia mail over the Internet and allows for the inclusion (or attachment) of multimedia data within a mail message.

Network News Groups

Network news groups let people with shared interests communicate about a particular subject area. News group services, which can be provided by e-mail, are a powerful tool for districts and their local communities to “discuss” topics of interest. The information shared through news groups is mainly simple text, which makes news groups useable over

low-bandwidth connections. News groups allow users to participate on their own schedule and, because the messages or "postings" are sent to and retrieved from a central repository, they do not overburden the electronic mailboxes of users. The effective use of a news group is directly related to the size and interests of the group.

Information Services

Probably the fastest growth in use of the Internet is with public information servers such as the World Wide Web. Others include Gopher, anonymous FTP, and WAIS. Bandwidth requirements for these services are a function of the type of service and also the role, whether client or server. Services that provide multimedia data will require more bandwidth than those that provide only simple text. In general, servers require more bandwidth than clients require because servers handle multiple simultaneous requests.

Name Services

A name service is critical to every network and must always be available. The domain name system (DNS) is the name service for the Internet. Every computer on the Internet (or using Internet protocols) has a unique address consisting of dotted-octet (xxx.xxx.xxx.xxx) IP addresses. Every computer should also have a unique name. These are of the form systemname.domain where there may be several qualifying domains (e.g., lahs.losalamos.k12.nm.us). In fact, it is possible to have several names for each address. The mapping between names and addresses is a function provided by the Internet's DNS.

As a client, every Internet computer accesses a DNS server to perform this translation between names and addresses. The bandwidth requirement for these small requests is low, yet the service is critical to the proper function of the network. In many cases the DNS system is provided by the Internet service provider. Running a DNS service locally provides more control over the allocation of addresses and the naming (and renaming) of those addresses within your domain. This is especially useful if systems are being moved, added or removed from the network and rapid updates to the DNS are required. The bandwidth requirement for a given server is driven by the number of requests and the need to query other servers for names and addresses not contained on the server.

File sharing

File sharing is one of the most common services among network computer users. These services fall into two broad categories, simple explicit file transfers and the more demanding full access of a file system over the network. Each type of service is a set of protocols that will run on top of a number of different network media and places its own set of requirements on the network.

The basic file service allows users to transfer files between networked computers. This type of service began with the earliest connections of computers over modems. Kermit, Xmodem, and other file transfer schemes provided a method for simple file transfers. The

best example of this type of service over a real network is FTP, the Internet file transfer protocol. FTP allows a registered user with accounts on two networked computer systems to transfer files between those systems. The use of the special user name "anonymous" allows public access to files on a system. This service, called anonymous FTP, is fraught with many potential security problems and must be configured carefully to avoid a security breach. The bandwidth requirement for an FTP client or server may be quite low if the transfers are few and the files are small.

The more sophisticated file services allow a network computer to "mount" a remote file system on a local computer. Once mounted, the files in the remote file system may be accessed in the same way as a local file on the local computer. The bandwidth required for this type of file service is usually higher than for a simple file transfer using FTP and is a function of the demand for service. Responsiveness to file requests is required for these connections to be viable. These types of file servers provide mechanisms for accessing only a portion of a file, thereby reducing the amount of data transferred. NFS, AppleShare, Novell, and Windows for Workgroups are examples of products that provide this type of network file service.

Conferencing

Conferencing services facilitated by computer networks range from multi-user, text-based systems to very demanding video teleconferencing systems with features that allow collaboration among people over long distances. The system determines the bandwidth requirements. Servers, in general, require significantly more bandwidth than clients. Common conferencing applications include IRCs, MUDs, and CU-SeeMe.

Printer Sharing

Printer sharing involves routing print jobs from many computers through the network to one or more centrally located printers. This is often a cost-effective way to provide many users with access to high quality printers with differing capabilities without having to buy a printer for each desktop computer system.

Terminal Connections

Terminal connections allow the user to connect a terminal over a network to a remote computer. The basic Internet terminal connection is telnet. Using telnet, the user of a terminal on a local system can connect to another system across the network and appear to have a direct terminal connection.

In many cases today, the "terminal" is actually a personal computer running software that emulates a particular type of terminal with a direct connection. On the server side, providing terminal services simplifies the method of connection between a terminal, emulated or real, and the system.

Terminal connections are most often used for connections to bulletin boards, to servers, and to so-called legacy systems, which typically run on large, mainframe computers and require a terminal connection. These terminal connections are all text-based and support graphics only if they emulate a now-antiquated graphics terminal. They do not support multimedia data, except as simple file transfers from the mainframe server to the client system over the terminal connection. Because of the text-based nature of the connection, the bandwidth requirement is low for both the client and the server. The bandwidth demand will increase on the server side if a large number of simultaneous connections is being supported.

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Appendix G: Glossary

AppleShare The product that provides a robust file server using Appletalk protocols.

Appletalk A collection of protocols developed by Apple Computer for file and printing sharing over networks.

ARA Appletalk Remote Access. The product that allows use of the Appletalk protocols over dialup modems.

bandwidth The amount of data expressed in bits per second (bps) that can be transmitted over a given data transmission medium. Contemporary usage in the computing field refers to bandwidth as the "rate" or "speed" of a network communciations line.

CAD Computer-aided design. A software program (and, often, a computer workstation) that allows the user to design a three-dimensional object. The term is usually applied to programs and workstations that are used to design engineering, architectural, and scientific models of physical objects.

CATV Cable television. A few cable television systems are beginning to offer data networking service in addition to the standard cable television service. CATV offers the promise of low-cost, high-bandwidth connection for WANs and especially the Internet.

CU-SeeMe A free videoconferencing program for use on Macintosh or Windows platforms and over the Internet. CU-SeeMe allows users to videoconference between any Internet sites. Cornell University and its collaborators hold copyright to the software.

domain name server An Internet site, or file server, identified by a unique name. The domain name constitutes the Internet address of a computer.

domain name system (DNS) A distributed database system that translates computer names into numeric Internet addresses and vice-versa for ease of use.

e-mail Electronic mail. E-mail systems allow users to exchange electronic memos (often including text, data, and graphics files as attachments) over a computer network. E-mail may operate on a LAN, a WAN, or the Internet.

FTP File transfer protocol. A login method that allows users to send or retrieve files over the Internet. Many Internet sites allow the public to retrieve files using the "anonymous" account name. These sites are called anonymous FTP servers.

Gopher A client/server program that makes available menus of information on the Internet. Gopher sites, or servers, allow users, or clients, to access information. Gopher is quickly being supplanted by WWW home pages.

HTML Hypertext markup language. A set of programming codes embedded in text or graphics on a computer that provide links to other text, graphics, or sounds. HTML is the standard for creating hypertext documents on the World Wide Web. (See WWW.)

IRC Internet relay chat. Live, multiuser, text-based chat facility carried by servers around the world.

ISDN Integrated services digital network. A worldwide standard for digital telephone service.

Internet International computer network based on a set of protocol standards for communication and data exchange. The Internet allows users to exchange e-mail and various kinds of electronic files (text, graphics, data, video, etc.), search data bases around the world, access remote files, participate in "newsgroups" on subjects of common interest, and otherwise communicate, share, and retrieve information. When written without the capitalized initial—that is, *internet*—the term refers to the particular set of protocols that are used over the Internet or other connected networks.

LAN Local area network. A LAN is a computer communications network used by a single entity (for example, a school) over a limited distance, which permits users to share information and resources. LANs are partly defined by their reliance on cabling (for example, twisted pair or fiber optic). If a segment of the network uses the phone system (even dedicated lines) or a satellite uplink, for example, it is considered a WAN. (See WAN.)

Listserv A type of e-mail server that maintains mailing lists and distributes e-mail to those addresses on the lists.

MIME Multipurpose Internet mail exchange. An extension to the basic Internet mail service, MIME allows for the inclusion or attachment of multimedia data within a mail message.

multimedia Computer applications or files that comprise video, voice, graphics, and text data in some combination.

MUD Multiple-user dungeons or multiuser dimensions. A virtual environment in cyperspace where people "meet" to interact, often in a text-based role playing or adventure game. MUDs often provide "rooms" where people interact through real-time communications.

MUSE multiuser shared experience.

NFS Network file system. A set of protocols that allows users to access files on physically remote network computers as if they were local. Thus, rather than using FTP to transfer a file to a local computer, the user can read it, write it, or edit it on the remote computer using the same commands that would be used locally. NFS was originally developed by Sun Microsystems, Inc. and is currently in widespread use.

POP Post office protocol. POP is used by e-mail applications to retrieve from an e-mail server. Works with SLIP/PPP connection. (See SLIP/PPP.)

PPP Point to point protocol. A communications protocol that enables a computer to connect to a network overa regular telephone line. Supports a TCP/IP connection over a modem, thus enabling full Internet access. (See SLIP.)

SLIP Serial line internet protocol. A protocol that allows a computer to connect to the Internet by a modem. SLIP is gradually being superseded by PPP. (See PPP.)

SMTP Standard mail transfer protocol. The standard used for transferring e-mail messages on the Internet.

TCP/IP Transmission control protocol/Internet protocol. A suite of protocols accepted as the standard for all Internet activity.

transmission medium The cable or other physical circuit that interconnects systems in a network.

video As defined for the Model Nets study, video is real-time, full-motion video transmission.

voice As defined for the Model Nets study, voice is real-time telephone transmission.

WAIS Wide area information server. A powerful system for looking up information in databases (or libraries) across the Internet.

WAN Wide area network. A WAN is a computer communications network used by multiple entities (for example, the schools within a school district) at geographically separate locations (and over longer distances than a LAN), which permits users to share information and resources. For the purposes of the Model Nets study, WAN was further defined as a network that was owned or managed entirely by a school district or site, thus distinguishing it from a LAN with Internet access. (See Internet, LAN.)

WWW World Wide Web. An international, Internet-based network of hypertext documents, which are often called "home pages" or "Web sites." Home pages can include text, graphics, sound, video, and other multimedia objects. Home pages provide links to other home pages or other information sources, such as e-mail, FTP, gopher, or telnet.

WWW also comprises a set of protocols (including HTML) and Internet services supporting the exchange of data. WWW home pages can be created and used on a single workstation, a LAN, or a WAN, in addition to the Internet. (See HTML, Internet.)

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